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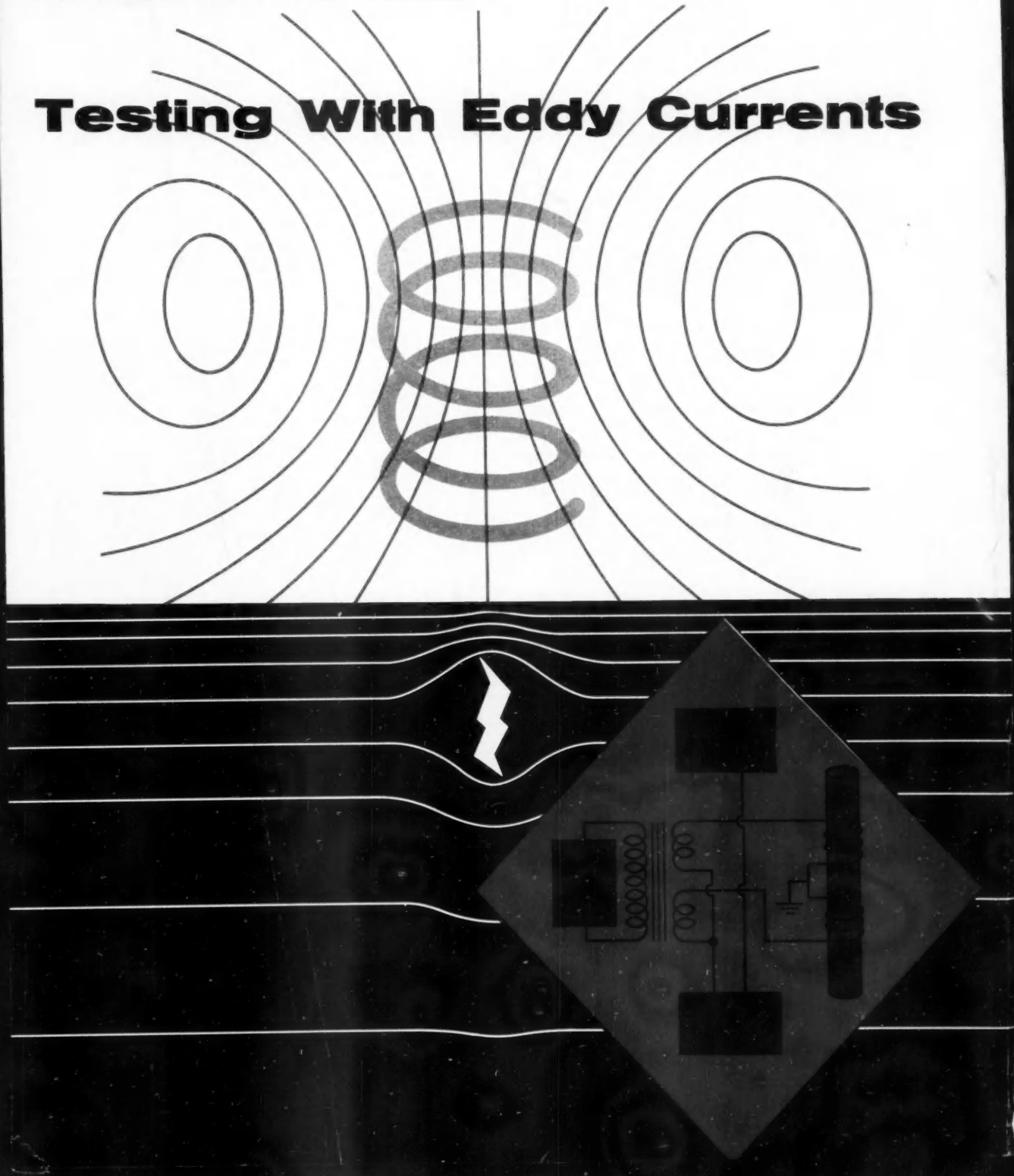
PRICE 50 CENTS

AUGUST 1957

Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

Testing With Eddy Currents



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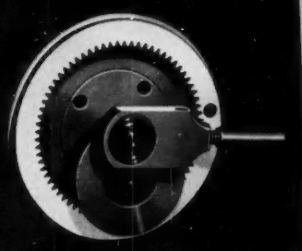


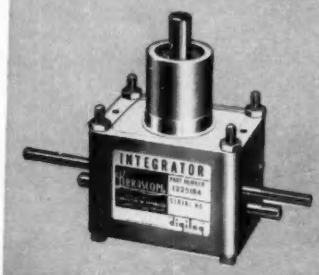
TYPICAL APPLICATIONS

Provides for instantaneous solution of problems involving the sine or cosine of an angular variable. Angular rotation is converted into a displacement proportional to sine or cosine of the input.

SPECIFICATIONS

Accuracy 0.2%
Stroke, peak to peak..1.500"
Size .....2"
Weight.....2 oz.

Ball and Disc Integrator



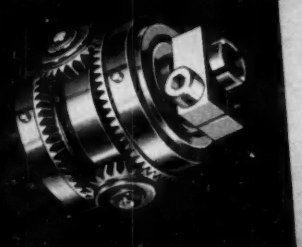
TYPICAL APPLICATIONS

A precision integrating mechanism for totalizing, rate determination and differential analyzing. Can also be used as a closed loop servo-element or accurate variable speed drive.

SPECIFICATIONS

Optimum reproducibility: .01% average
Force to move carriage: 5 oz. max.
Shaft travel: 1½"
Input torque: 2 in. oz. max.
Size: 1⅞"x 2¾"x 3¼"
Weight: 21 oz.

Hollow Shaft Differential



TYPICAL APPLICATIONS

Applicable to angular sums, angular velocity sums or sequence operations. May be installed or removed without disassembly of unit or differential. High accuracy.

SPECIFICATIONS

Inertia: approx. .074 oz. in.²
Max. backlash: 0° 10" at 2 in. oz.
3 point contact with spider gears.
Precision ball bearings.
Size: 1"x 1-3/16"
Weight: 1¼ oz.

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It's the first really *different* drift stabilization and error detection system for large-scale analog computers. It's automatic—it's continuous—and it has a built-in watchdog.

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• • •

For detailed technical data on the new GEDA A-14 Automatic Stabilization System, ask for your personal copy of the paper: "A Reliable Method Of Drift Stabilization And Error Detection In Large-Scale Analog Computers."

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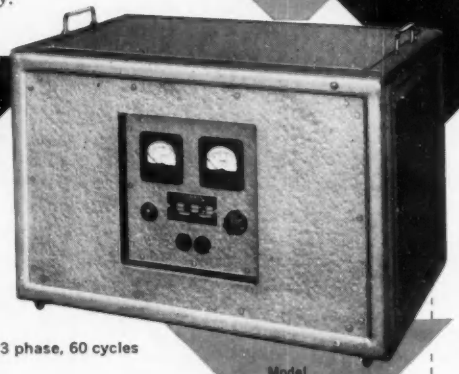

Model MR2432-100XA

Additional Specifications:

Ripple: 1% RMS

AC Input: 208, 230 or 460V ±10%, 3 phase, 60 cycles

Weight: 230 lbs.

MODEL NO. MR917-100XA — also available: specifications same as above except output of 9—17 volts DC.

When you require a power supply, SPECIFY PERKIN, for a wider range of standard models and immediate delivery from stock.

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Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
28-5VFM	0-32 V	5	15-20% (24-32V range)	115 V 1 phase	2%
28-10WX	24-32 V	10	±½%	100-125 V 1 phase	1%
MR532-15A	2-36V	15	±½%	105-125V 1 phase	1%
28-15VFM	0-32 V	15	15-20% (24-32V range)	115 V 1 phase	5%
M60V	0-32V	25	±1%	115V 1 phase	1%
MR1040-30A	5-40V	30	±1%	100-130V 1 phase	1%
28-30WXM	24-32V	30	±½%	100-125V 1 phase	1%
28-50WX	24-32 V ±10%	50	±½%	230 V* 3 phase	1%
MR2432-100XA	24-32V	100	±½%	208/230V* 3 phase	1%
MR2432-200	24-32 V	200	±½%	208/230V* 3 phase	1%
MR2432-300	24-32 V	300	±½%	208/230V* 3 phase	1%
MR2432-500	24-32 V	500	±½%	208/230V* 3 phase	1%

*±10%. Also available in 460 V ±10% AC input. Will be supplied with 230 V input unless otherwise specified.

6, 12, 115 Volt Models

	Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
6 Volt	6-5WX	6 ±10%	5	±1%	95-130 V 1 phase	1%
	6-15WX	6 ±10%	15	±1%	95-130 V 1 phase	1%
	6-40WX	6 ±10%	40	±1%	95-130 V 1 phase	1%
12 Volt	12-15WX	12 ±10%	15	±1%	95-130 V 1 phase	1%
115 Volt	115-5WX	115 ±10%	5	±½%	95-130 V 1 phase	1%
	MR1512S-5	15-125	5	±1%†	95-130 V 1 phase	1%††
	G125-25**	115-125	25	±1½-4%	230/460 V 3 phase	5%

**Germanium Rectifier Unit ††Increases to 4% @ 15V.
†Increases to 2% @ 15V.

PERKIN POWER SUPPLIES

Control ENGINEERING

AUGUST 1957 VOL. 4 NO. 8

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

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Sweltering listeners packed a room at the Sheraton-Mt. Royal in Montreal to hear an AIEE Feedback Controls Systems panel discuss the objectives and trends in control systems progress. Cut shows Gordon S. Brown, head of MIT's EE Dept. and CtE's chief consulting editor, proclaiming that feedback control practice must embrace all its real parts. The other panel members — H. Chestnut, GE, chairman; O. Orbom, Allegheny Ludlum; C. S. Herwald, Westinghouse; H. Palmer, GE; E. M. Grabbe, Ramo-Wooldridge; and D. P. Eckman, Case Institute — followed Gordon's lead in fretting at the fetters of feedback in AIEE. See *What's New* in September for full coverage of the panel's contribution plus the ensuing discussion.

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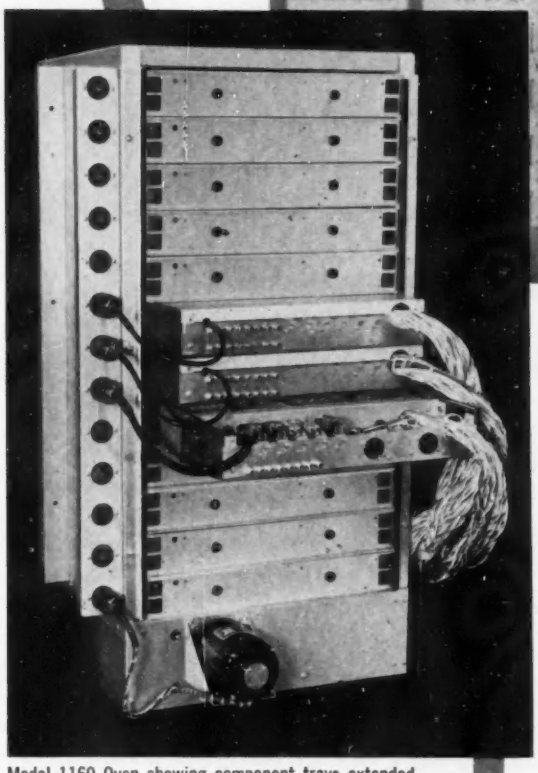

Model 1160 Oven showing component trays extended.

New Double Oven Insures Computer Accuracy

The newly-designed Beckman/EASE* constant temperature oven brings unprecedented thermal stability to passive computing elements, yielding laboratory accuracies under field conditions. Actually an "oven-within-an-oven," Model 1160 holds accuracies of .002 percent despite ambient changes of 70 to 110° F. and line voltage changes from 105 to 130 volts. Simultaneous changes in ambient or line voltage do not affect this accuracy. Naturally, as the environment improves, so does the accuracy.

Capacitors can be adjusted through oven walls and high component capacity permits easy expansion. All components are adjusted initially to .001 percent accuracy.

Four years of careful design developed this remarkable oven. Such problems as eliminating temperature "leak" through 1,000 copper wires had to be overcome.

The EASE* double oven makes possible — for the first time — a computer system independent of any temperature change.

For further information on the Model 1160 Oven and the EASE* 1100 Series Computer, please write Dept. L8

SPECIFICATIONS—

Model 1160 Oven

1. VOLUME 29" x 8" x 14½"
   Provides adequate room for
   a. 1056 precision wirewound resistors
   b. 80-1 μf polystyrene capacitors
2. TEMPERATURE DATA (for given environment)
   a. Set point, 45° C ± 0.05°
   b. Variation**
      1. Resistor Region,
         ±0.5° C max.
         ±0.3° C nominal
      2. Capacitor Region,
         ±0.3° C max.
         ±0.1° C nominal
3. ENVIRONMENT
   a. Ambient temperature range 70° F. to 110° F.
   b. Line voltage 105 to 130 volts a.c.

*** Variation in temperature means the maximum deviation in instantaneous local temperature due to long term drift and any combination of environment and line voltage changes within stated range.*

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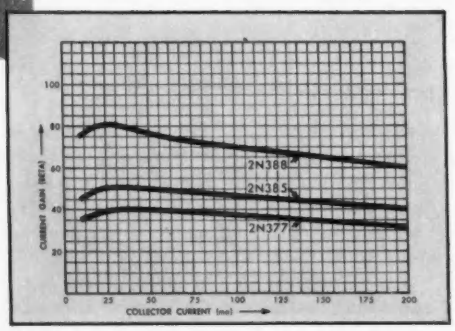
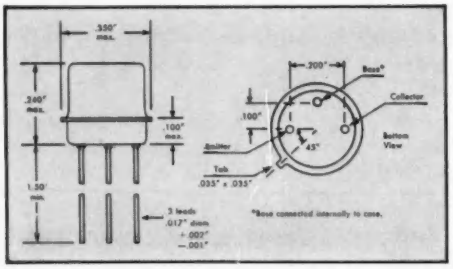
New Computer

Types 2N 377.... 2N 385

Stability during life sets new standard for reliable use



Typical current gain vs. collector current



Triangular basing arrangement of the new computer transistors lends itself to printed circuit board insertion and dip soldering techniques.

New Sylvania NPN germanium alloy junction transistors, types 2N385, 2N377 and 2N388, are specifically designed for computer use. Higher, more constant beta over a wide range of operating conditions and fast switching time make the new Sylvania units ideal for computer and switching applications. They meet environmental tests typical of those required in military applications. In addition, the new Sylvania computer transistors meet RETMA size group 30 dimensions.

The outstanding characteristics of the new Sylvania transistors have been achieved in two ways—by new non-symmetrical design and by additional production steps. The optimum size relationship between emitter and collector has been determined for superior collector efficiency. This inherently better design is stabilized in production by carefully controlled surface treatment.

New Sylvania techniques are not only responsible for higher beta in the 2N385, 2N377 and 2N388 but for more constant beta at changing current levels. In addition, the design of the three types significantly improves leakage stability. Total dissipation is conservatively rated at 150 mw with ambient temperature at 25° C.

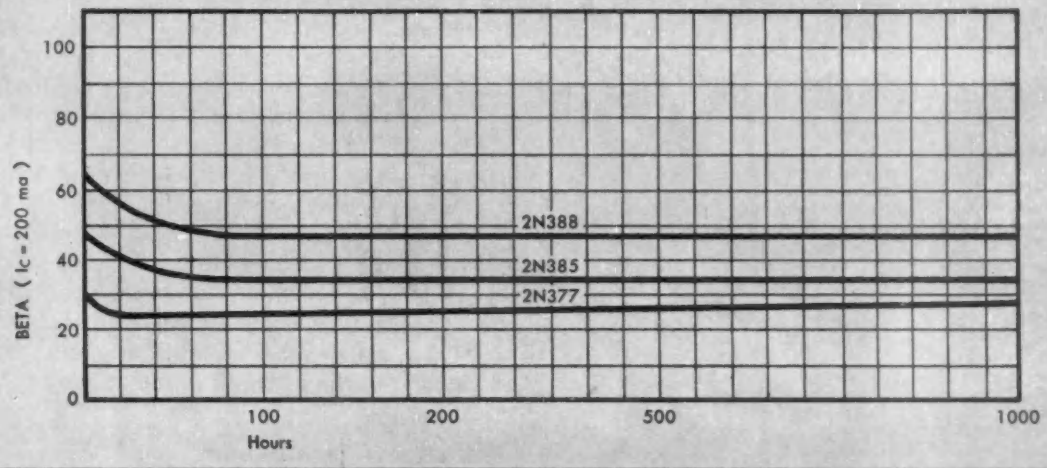
Thus, new and greater stability and reliability for computer and switching operations are built into these latest transistor developments from Sylvania. Call your Sylvania representative for further information.

"Sylvania—synonymous with Semiconductors"

Transistors

....2N 388

1,000-hour evaluation of the new Sylvania transistors at 100° C shows a new high in beta stability throughout the test after a small initial change.



Typical Characteristics (25°C)

	2N385	2N377	2N388
Collector Cut-off Current, I_{CO} V_{CB} = 25.0 emitter open	5 ua	6 ua	6 ua
Emitter Cut-off Current, I_{EO} V_{EB} = 15.0, collector open	5 ua	6 ua	6 ua
Current gain, B V_{CE} = 0.75, I_C = 30 ma	60	40	80
Current gain, B V_{CE} = 0.75, I_C = 200 ma	45	30	60
Frequency Alpha Cut-off, $F_{\alpha CO}$ V_{CE} = 5.0, I_C = 10 ma	6.0 Mc	4.0 Mc	8.0 Mc
Collector Current I_C (-5,10K) V_{CE} = 20 V, R_{BE} = 10K, V_{BB} = -5V	10 ua	10 ua	10 ua
Storage or junction temperature	100° C.	100° C.	100° C.

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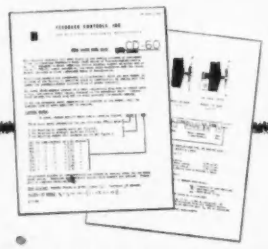

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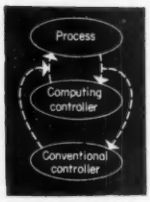
SHOPTALK

SEPTEMBER'S NEARLY HERE AGAIN

Yup, this is the 36th issue of CtE and just one away from our Third-Anniversary special. Like our other September issues, this one will be "themed" to an important phase of the control engineering field. As you will remember, last year it was "How to Practice Control Systems Engineering". This time we've taken a slice out of this broad topic—the new and interesting area of computing control.

Early in November 1956, shortly after our last September issue was distributed, the decision was made to devote September '57 to computing control. Associate Editor Harry Karp took over the reins, studied the field, organized a logical series of articles, carefully selected outstanding authors, and held the whip over both authors and editors to get the material in and edited. The result—a cross-section of computing-control case histories and a comprehensive coverage of the methods and functions in designing computing-control systems—will be well worth your reading effort. In case you're interested in the accompanying sketch, we call it "Harry's Loop" because it was what Harry used in explaining his ideas on computing control to the rest of us.



PhDs and MDs Exchange Thoughts

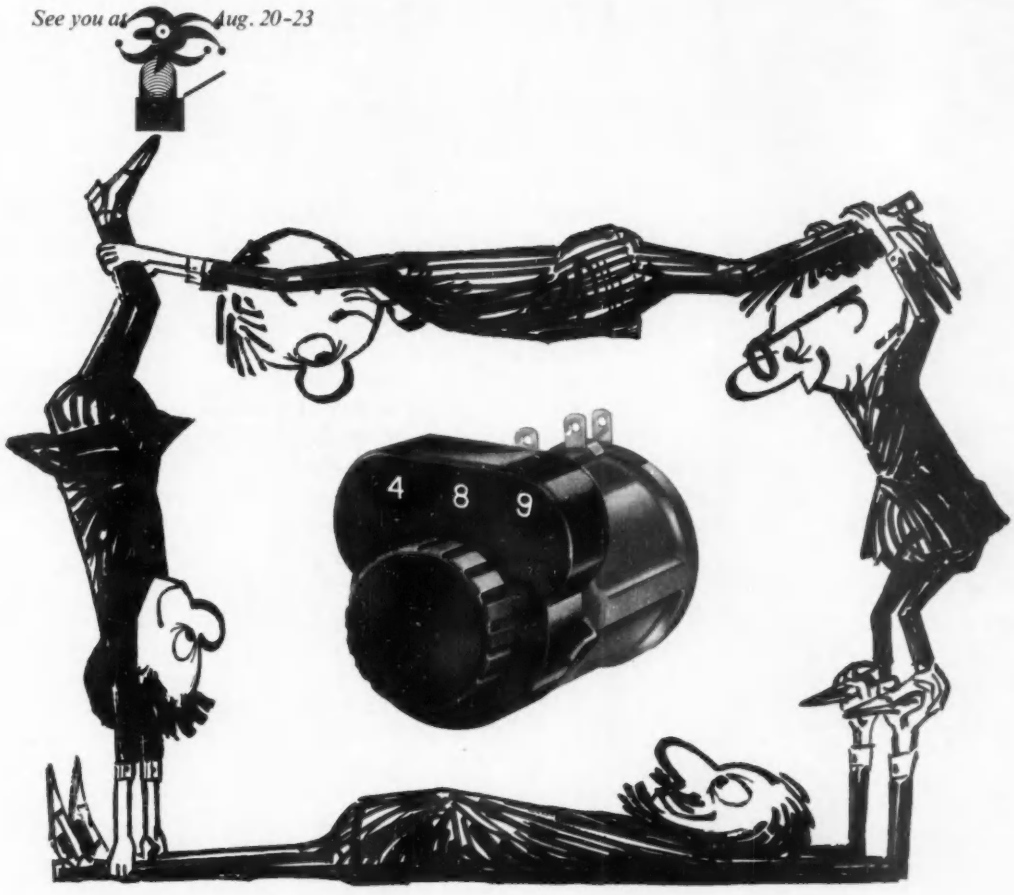
There's the old story about the PhD who was awakened in the middle of the night by a phone call. To the party on the other end of the line, who wanted a doctor (MD) to tend his sick child, the PhD replied, "I'm a thinking doctor, not a cutting doctor." A short while ago the PhDs who earn their keep thinking about instrumentation and control were brought together with the MDs at the "Conceptual Clinic for New Instrumentation for Medicine and Biology" cosponsored by the Foundation for Instrumentation, Education & Research and the New England Institute for Medical Research. For a first hand report by Associate Editor Lew Young (with MIT's Norbert Weiner, right, and FIER Executive Director Lloyd Slater, center), see p. 27.

Putting the Spotlight on Modulators

"Servo Modulators—I", p. 65, starts a group of four articles covering all phases of control-system modulators: applications, types, characteristics, circuits, and commercial and home-made models. Bill Barber of Sperry Gyroscope and Larry Klivans of Radioplane will split the work. After all four have been run, they'll be available in one reprint.

Wescon

See you at *Aug. 20-23*



A Dial to reckon with

When position is everything, you can count on the new DIGIDIAL* ten-turn decimal-counting dial... for indicating shaft position from 0° to 3,600°... with reading resolution of 0.05% of full scale or better.

The DIGIDIAL reads by the numbers. This means farewell to interpolations and operator errors... hail and hello to fast, accurate reading from as far as six feet away... from just about any angle except behind the panel. You'll welcome its compact construction, light weight, simple installation and smooth operation. You'll utter gleeful greetings to the positive, non-distorting locking mechanism.

If position is important to you, you'll want to know more about the DIGIDIAL... to get the whole story, write for data file 82G.

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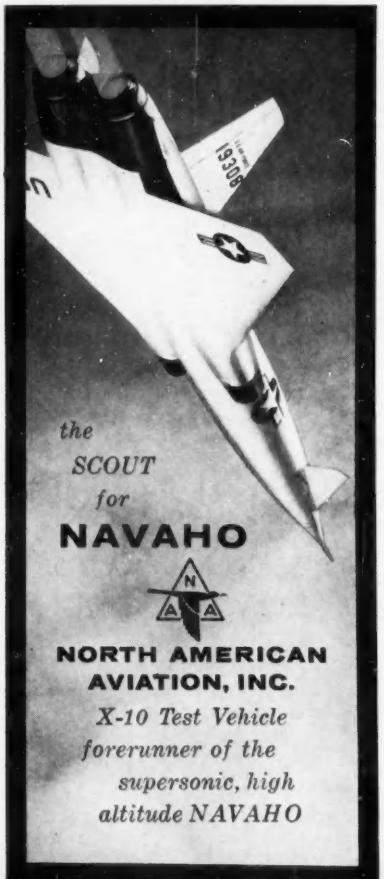

IN THE X-10,
Statham transducers gathered pressure and acceleration data in North American Aviation's program to prove out the aerodynamic design as well as the guidance and control systems for NAVAHO.

WHEN THE NEED
IS TO KNOW...FOR SURE
SPECIFY STATHAM

Accelerometers
Pressure Transducers
Load Cells

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Statham
LABORATORIES
LOS ANGELES 64, CALIFORNIA

FEEDBACK

PROBLEM FORUM

Two key factors stimulate the current trend toward increased use of protective interlocks for steam generators:
▸ increased unit size, and with it, hazard to larger investment through physical damage or loss of power-generating capacity
▸ greater responsibility per operating man because of more-automatic and less-manual control

Protection of people and equipment is the intent, but if the interlock system falsely shuts down equipment, the result can be deterioration in the continuity of service. The problem and solution presented here show that careful system specification, installation, and on-the-job adjustment of switch set-points are essential in guarding against malfunction and the eventual mistrust of interlocks.

Submit to us *your* problem in specification, application, or operational test. We'll not only get known experts to work on it, but we'll publish it so that readers of the magazine can have a crack at it, too. And remember, all published problems and answers earn awards.

Problem

The furnace pressure switch (for both high draft and high pressure) is the "utility infielder" of safety interlocks for large balanced-draft steam generators. It provides back-up protection for loss of air, detects a tube rupture serious enough to snuff out the fire, and detects sudden loss of fire at substantial loads. The most controversial thing about the switch is its proper application. Because their settings did not conform to furnace dynamic characteristics, a large number of those installed have been later disconnected.

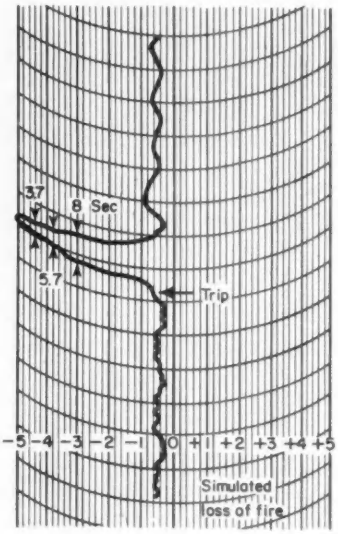
By what operational test method can one determine correct installation and match the switch setting to the furnace characteristics?

Solution

To the Editor—

The answer is contained in a paper (unpublished) which was presented at the May 2-3, '57 meeting of the Southeastern Electric Exchange, Production Committee, Engineering & Operating Section, Miami Beach, Fla.

Place an orifice and a capacity tank between the furnace connection and the switch. When properly sized they will attenuate normal fluctuations in furnace pressure but will permit sustained and dangerous upsets to trip the switch. The greater the deviation from normal, the faster the pneumatic filter system acts.



Connect a high-speed test recorder to the draft tap and record actual furnace pressure during periods of normal and critical boiler conditions. Set the furnace pressure switch to trip at measurements greater than the pressure which occurs during normal conditions but to less than the pressure developed when the flame completely fails (simulate by tripping all operating fuel feeds simultaneously). Size the orifice and capacity tank so that they pass an impulse slightly greater than trip pressure for 2-3 sec in gas-

convert to digital recording

WITH DATEX MODULAR DIGITAL COMPONENTS

QUICKLY

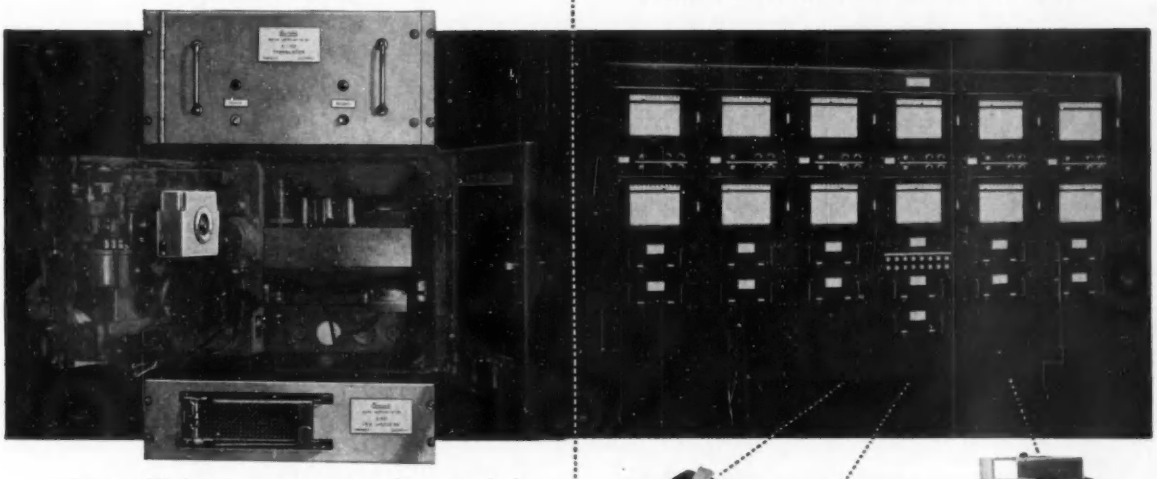
EASILY

ECONOMICALLY

PROVE IT—with low cost single channel system. EXPAND—into multiple channel systems using same components.

SINGLE CHANNEL

COMPLETE MULTI-CHANNEL SYSTEMS FOR: WIND TUNNEL TESTING; PROCESS LOGGING; ENGINE TEST FACILITIES, ETC.



Equip self-balancing potentiometers of any standard make with DATEX single channel kit. No special gearing, modification, or complex brackets required. Used by leading recorder manufacturers for digital recording.

Accuracy: ± one digit in one thousand.

DATEX SHAFT POSITION ENCODERS:

Low inertia effects; 1000 to 2000 digits per shaft revolution. Only 13 leads for readings from 0 to 1500. Non-ambiguous coding, no mechanical anti-ambiguity devices required, only one moving part. Can be read out while rotating. Negative sign and non-linear calibration available. Other models available with readings to 10^6, with binary, gray, binary decimal and excess 3 coding.

CLARY PRINTER-ADDER IBM TYPEWRITER IBM SUMMARY PUNCH

Giannini digital data handling and recording systems can be adapted to many processes that require rapid and/or continuous recording of precise information.

The inherent simplicity of the DATEX Building Block concept, which utilizes standard major elements to make either small or large multi-channel systems, allows expansion by the addition of other modular elements. Various input or output arrangements are possible by using standard switching or sequencing techniques. Combinations of outputs (punch cards, typewritten tabulation, visual light bank, printed tape or punched tape) are readily obtained by the addition of proper modular units. Basically electro-mechanical in design, DATEX systems use simple tested components of proven reliability to give superior performance.

Literature available upon request.

Write us concerning your data handling problems—

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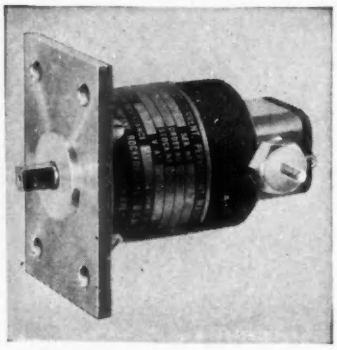
Giannini DATEX DIVISION
MONROVIA, CALIFORNIA

G. M. GIANNINI & CO., INC. • PASADENA 1, CALIFORNIA

BARBER COLMAN **tach generators**

for accurate speed indications and rate control applications



up to 40 volts per 1000 rpm within plus or minus 0.5% linearity over the operating range with very low slot and commutator ripple. Barber-Colman tach generators are available in three different frame sizes with maximum rated outputs up to 7000 rpm or 100 volts, whichever occurs first. Typical applications include controlling antiskid circuits for wheel braking . . . surface control systems of guided missiles . . . indication of film speed rate in aerial cameras . . . and rpm indication of variable speed drives in industrial machines, processing equipment and similar production units. Many variations of Barber-Colman tach generators are available for special applications. Send for free technical bulletin.

The complete line of Barber-Colman d-c motors

. . . includes both permanent magnet and split series types . . . in various mountings and speeds with outputs up to 1/10 hp. Ideally suited to power electro-mechanical actuators, switches, and programming devices. Also available with gearheads or blowers for special applications. Whatever your problem involving small d-c motors, let Barber-Colman Company engineers help you find the solution. Write for free Catalog F-4344.

BARBER-COLMAN COMPANY
Dept. T, 1848 Rock Street, Rockford, Illinois

FEEDBACK

fired units and for 3-5 sec in coal-fired units. The setting should not exceed 3-4 in. of water (gage), which represents normal furnace-wall design strength with the allowance for wind pressure subtracted. The figure on page 10 shows what the high-speed chart record will look like.

W. A. Summers
Ebasco Services, Inc.
New York City

Encore, encore

TO THE EDITOR—

The article by B. E. Powell on "Basic Concepts of Feedback Control" in the April issue is EXCELLENT. He starts at the beginning, he defines his terms (e.g., frequency response), he says how he obtained his data (that is, by calculation or by experiment), he gives a simple example with numbers, and he offers a brief practical conclusion. Please get further articles like this to add reset and rate actions.

Name withheld
Chicago, Ill.

Metal quality control—then and now

TO THE EDITOR—

The Metals Laboratory is currently conducting metallurgical training courses for Navy inspection personnel. In this connection, we are interested in obtaining reprints of the article "Eddy-Current Testing: A New Tool Makes Inspection Automatic", by Richard Hochschild, in the October issue of CtE. If this and other similar reprints covering electromagnetic test equipment for metal quality control are available for general distribution, the Metals Laboratory will appreciate receiving copies of each for distribution to inspectors attending the classes scheduled during the fiscal year 1958.

W. R. Angell
U. S. Navy Metals Laboratory
Munhall, Pa.

A second Hochschild article, based on two and a half years' experience applying his techniques, appears on page 79. Reprints are available. Ed.

Give credit where it's due

TO THE EDITOR—

On page 38 of the March issue of CONTROL ENGINEERING you carry an article relative to Panellit Services as caretaker of Tidewater's giant Flying A Refinery. The article reads as though Panellit has the responsibility for the entire maintenance of the refinery rather than for the maintenance of instruments alone, which is the limit of their responsibility.

Catalytic Construction Co. has the contract for the mechanical maintenance of the entire $200,000,000 installation and negotiated the union agreements under which all maintenance work in the Tidewater Refinery is performed.

We are, of course, working side by side in complete harmony with our friends of Panellit, but are also proud that we were awarded the largest contract for general maintenance ever made in the petroleum industry. We would appreciate your setting the record straight in this matter.

Alan McCone
Catalytic Construction Co.
Philadelphia, Pa.

There we go; our semantics are showing again. We regret the possibile misinterpretation; our intentions were to report the information contained in a news release and later substantiated by trip notes. One section of these trip notes, which formed the basis for our lead news story in June (page 24), read: "Tidewater is doing no maintenance of instruments on their own. Panellit has a contract for maintenance, not only of the information system, but of all instrumentation. As a result, Tidewater's instrument group at Delaware City consists of just one man, Ed Roth, Instrument Coordinator." Ed.

Information please—on literature

TO THE EDITOR—

I have been quite interested by your article, "Analog to Digital Converters", printed in the April '57 issue of CONTROL ENGINEERING. My firm is busy in France with problems in data logging. The information in the article made up my mind on what equipment to use.

I should be very pleased to get a paper listed in the references of the article. It is "Transistor Circuitry for Analog-to-Decimal Conversion", presented by F. H. Blecher at WESCON, Aug. 23, '56. Because it does not seem to be available in France, I would be very grateful if you could tell me how to get it in the U.S.A.

The Director
SEREIM
Paris, France

IRE did not publish this paper, nor, to our knowledge, has it been

published anywhere. To obtain a copy, write to the WESCON business office, 342 La Brea, Los Angeles 36, Calif. Mention the session title ("Transistor Circuits: Switching and Computer Applications"), date, and chairman (M. S. Kesselman). Ed.

Gremlin derates one product and upgrades another

To the Editor—

On page 68 of the May '57 issue of Control Engineering you ran a new product news release covering two new Beckman/Helipot motor-generators. We issued two separate releases and evidently in combining them into one story an editorial gremlin switched some of the figures.

The story reads, "A 60-cps model features a minimum stall torque of 2.35 oz-in. and a stall acceleration of 29,000 rad per sec^2. On the 400-cps model minimum stall torque is 4.0 oz-in. and acceleration is 49,000 rad per sec^2."

Actually the 60-cps model has a minimum stall torque of 4.0 oz-in. and a stall acceleration of 49,000 rad per sec^2. The 400-cps model has a minimum stall torque of 2.35 oz-in. and acceleration is 29,000 rad per sec^2.

We would greatly appreciate it if the record could be set straight and the figures changed to protect the innocent.

M. A. Pines
Beckman/Helipot Corp.
Newport Beach, Calif.

Mea culpa, says our New Products editor. Mr. Pines' detailed letter sets the record straight, we believe. Ed.

Seeks participants in joint R&D

To the Editor—

We are very pleased with the mention made of Case in your editorial, "Why Not Joint R&D?", which appeared in the June 1957 issue of Control Engineering. As you are aware, the work of the Process Automation Group at Case under the direction of Dr. Donald P. Eckman has been supported since 1953 by four industries as well as the institute itself. Report I of their activities up to 1956 was well received by these sponsors. The self-checking and feedback feature, which they developed, is recognized as a major breakthrough in the science of automation.

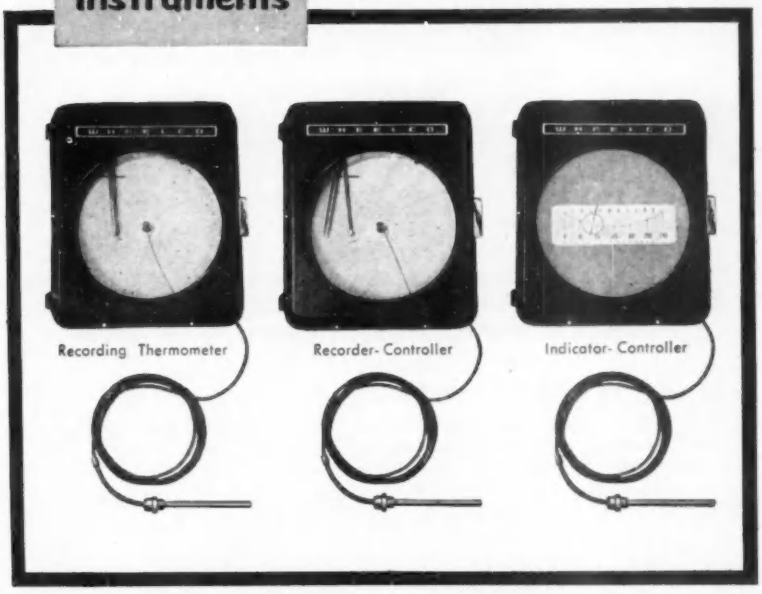
Our work is continuing under the same principle of joint research and development with several industries.

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

New! 4000 Series Thermotrols for Indicating, Recording, and Controlling



New 4000 Series Thermotrols for indicating, controlling, or recording service have standard operating ranges of –40 to 1000° F. All are mercury-actuated with recorders being available as single-, two-, and three-pen units. A wide variety of control forms is possible because of plug-in chassis design.

Other outstanding features of the new Thermotrols line include: Invar metallic compensator for case, friction-free pen arms, electronic control action for controllers with the Wheelco "Electronic Link," and electric clock chart drives.

Bulletin F-8042 has more data on these new Thermotrols. It's available from your nearby Wheelco field engineer.

BARBER-COLMAN COMPANY

Dept. T, 1548 Rock Street, Rockford, Illinois

BARBER-COLMAN of CANADA, Ltd., Dept. Q, Toronto and Montreal, Canada

Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Electrical Components • Small Motors • Overdoors and Operators Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

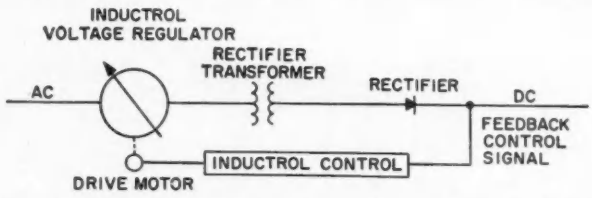
GENERAL ELECTRIC

VOLTAGE REGULATION IDEA FILE

by C. A. Neumann

ENGINEERING DESIGN IDEA: A.C. Controls D.C.

General Electric Inductrol* a-c induction voltage regulators can control d-c voltage or current. Here's how:



Inductrol regulators compensate for a-c line variations, rectifier aging effects, regulation as d-c load current varies, hold voltage (or current) to ±1%.

DESIGN BENEFITS: Inductrol regulator drift-free controls always keep voltage settings at desired level. Cost is low.

RADAR APPLICATION IDEA:

New England radar manufacturer uses three single-phase Inductrol voltage regulators to give precise individual phase regulation, hold voltage to ±1%. In addition a three-phase, motor-operated, manually-controlled Inductrol regulator is used for tube warm-up. Power can be increased by raising voltage from 0 to 600 in either two seconds or 30 seconds.

DESIGN BENEFITS: Easy-to-install, Inductrol voltage regulators introduce no waveform distortion into electronic systems.

COMPUTER APPLICATION IDEA:

Massachusetts computer manufacturer got line stability and proper tube warm-up by using both voltage stabilizer and voltage regulator. One Inductrol voltage regulator now does both jobs.

DESIGN BENEFITS: Inductrol voltage regulators have an excellent space factor, require little maintenance. They neither affect, nor are affected by, system power factor.

HEAT TEST IDEA:

Boston electronics firm uses battery of infrared quartz lamps to simulate missile in-flight heat conditions. Lamps, energized suddenly on this 208-volt circuit produced rapid heat, but lack of warm-up time caused expensive lamp mortality. A complicated and expensive wiring-switching arrangement was considered, discarded in favor of 3-phase automatic Inductrol voltage regulator.

DESIGN BENEFITS: Inductrol voltage regulators have no brushes to maintain or replace; are rugged, designed for long life; are extremely accurate and reliable.

FOR MORE INFORMATION write Section 425-8, General Electric Company, Schenectady 5, N. Y.

*Trade mark of General Electric Company for Induction Voltage Regulators.

Progress Is Our Most Important Product

GENERAL ELECTRIC

FEEDBACK

However, to accomplish all that we had hoped for in phase two of the overall program still requires more participating industries than we have agreements with to-date.

We are convinced that many industrial R&D problems can be solved through co-participation by industry and the engineering-scientific academic institutions. It saves companies the cost of technical manpower and facilities for research in activities not of immediate interest. From a broad viewpoint, joint sponsorship of large programs permits the financial support of larger numbers of graduate students, thus increasing the number of technically trained engineers.

It is a very practical means of solving industrial problems, increasing technical manpower, and increasing the support to educational institutions.

We heartily endorse your editorial.

Robert H. Thomas
Case Institute of Technology
Cleveland, Ohio

Let the Editor know if your company is interested in participating in the continuation of the process automation project. It is worthy and technically sound. Ed.

Feedback shapes an article

To the Editor—

I read with interest the article by M. Phister Jr. and E. M. Grabbe, "'Fitting the Digital Computer Into Process Control", and noted with approval your increased coverage of chemical process applications in your June issue.

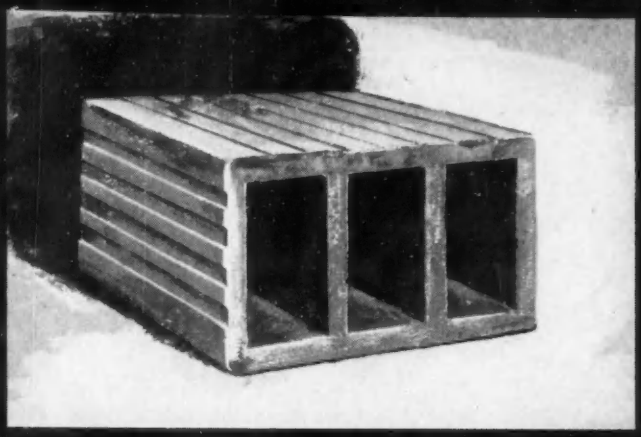
I must reply at once to a common misconception that the Drs. Grabbe and Phister passed along. In discussing the measurement of catalytic conversion, they stated several times that process analyzers were not available to measure catalytic conversion.

The Thermal Catalytic Gas Analyzer has the unique ability of continuously measuring catalytic conversion as well as continuously measuring concentrations in hydrocarbon streams with the reliability and stability of a good thermocouple.

Unfortunately this analyzer has not been as well publicized nor as well exploited as its value and usefulness demand. We hope to eliminate this lag in the information loop, in the near future.

Marvin D. Weiss
Fischer & Porter Co.
Hatboro, Pa.

Weiss' thermal catalytic gas analyzer



No Margin for Air— No Margin for Error

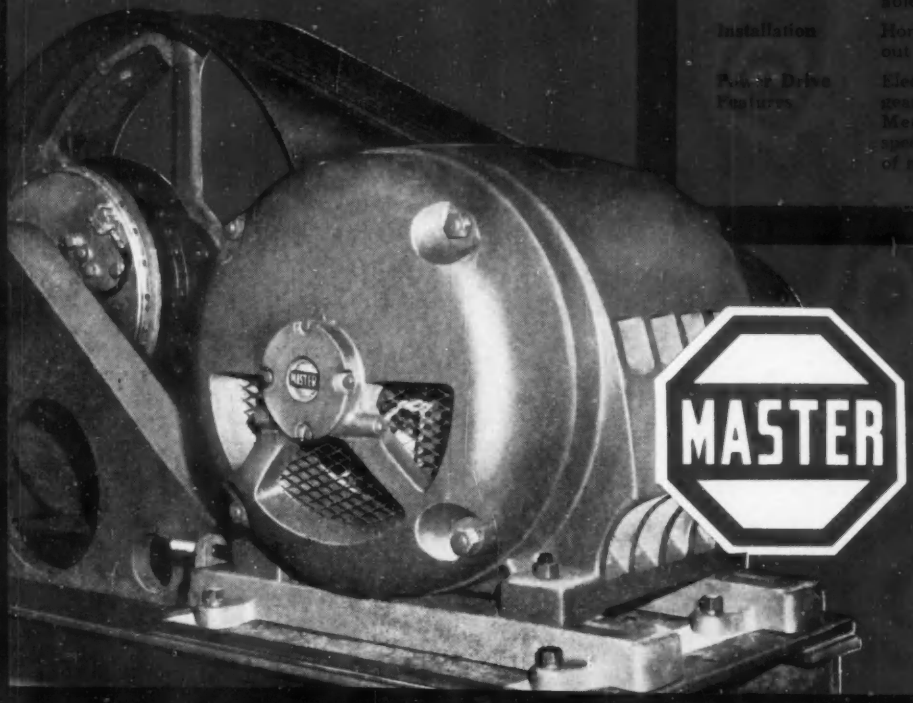
ANOTHER DRIVE REQUIREMENT MEETS ITS MASTER

Yes, it's a fact—unless you remove the air from the clay, you get a no-good tile. And whether air is your problem, or not—error is always a problem. And it's never a mistake to come to Master for the right power drive. In every kind of industry, Master customized package drives give you the utmost in flexibility, compactness and performance.

Here, the primary requirement is power—and the husky, big 200 H.P. Master fills the bill year in and year out. Your requirements might be better met by integrating Master components into a single, efficient, compact unit for the right horsepower, right shaft speed and right mounting features. What are they?

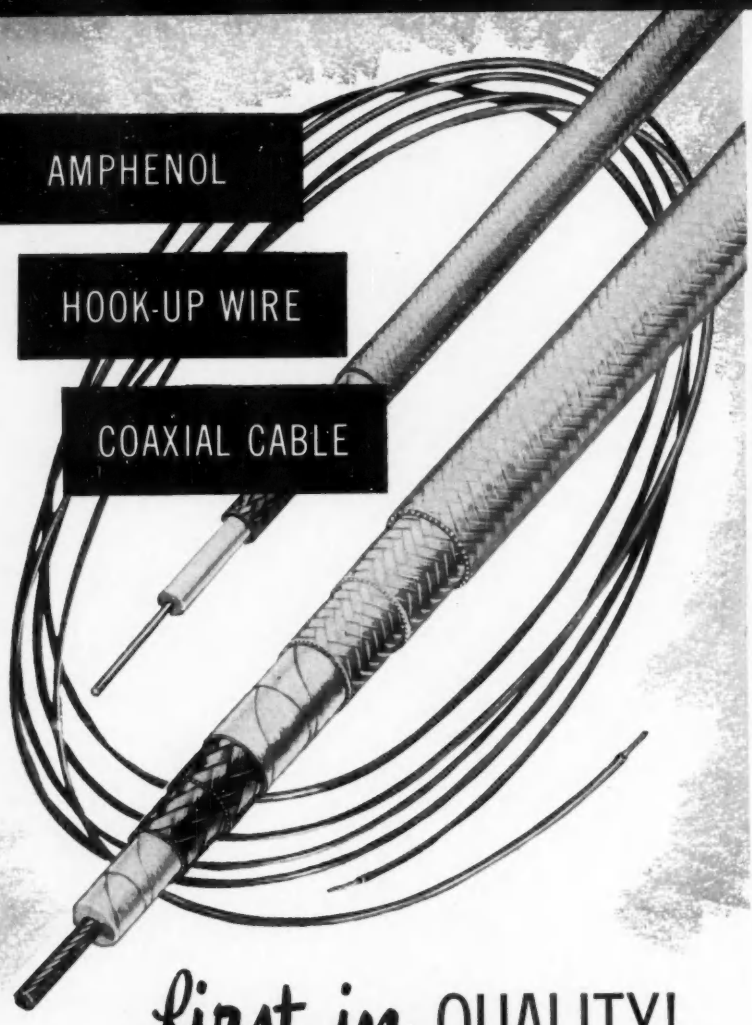
A husky 200 H.P., 440 volt squirrel cage induction Master Motor powers this 14-ton De-Airing Brick and Tile Machine with a capacity of over 3000 bricks per hour. Two parallel shafts carrying pug knives work clay, pass it into vacuum chamber with auger cylinders where it is finished and discharged.

Motor Ratings	½ to 400 H.P. All phases, voltages and frequencies.
Motor Types	Squirrel cage, slip ring, synchronous, repulsion-start induction, repulsion, direct current.
Construction	Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.
Speeds	Single-speed, multi-speed, and variable speed.
Installation	Horizontal and vertical, with or without flanges and other features.
Power Drive Features	Electric brakes (2 types)—8 types of gear reduction up to 60 to 1 ratio. Mechanical and electronic variable speed units—fluid drives—every type of mounting.



MASTER

THE MASTER ELECTRIC COMPANY
DAYTON 1, OHIO



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To its large family of Teflon* cables AMPHENOL now adds high temperature Teflon Hook-Up Wire. Made to the same high standards of quality, AMPHENOL Hook-Up Wire provides these reliability features:

CONCENTRICITY of Teflon insulation over tightly stranded wire—wire won't be scraped or unstranded during processing

40 MICROINCHES SILVER PLATING minimum on all wires—free from dirt or oxide for easier tinning

100% INSPECTION of every foot produced—11 Major Quality checks during manufacture

MADE TO MIL-W-16878B in types E and EE—wide variety of colors and gauges

For the *most reliable wire product* available, specify AMPHENOL's new Teflon Hook-Up Wire!

*E. I. DuPont Registered Trademark

AMPHENOL ELECTRONICS CORPORATION *chicago 50, illinois*
AMPHENOL CANADA LIMITED *toronto 9, ontario*

FEEDBACK

sounded so good that we have signed him up to prepare an exclusive article covering its basic operation, characteristics, applications, and means of tying into closed-loop control systems. Ed.

Another company goes south

TO THE EDITOR—

I thought you might like to know more about what is going on here at Airpax. . . . While other companies have been publicizing their plans, Airpax has quietly moved its Central Engineering Div. to Florida. . . . The company decided at the end of last year that the growing market for components going into control equipment (such as our Ferrac magnetic amplifiers and Magmeter tachometer transducer) warranted expanding the Central Engineering Div. The problem was how. Locating the division in Florida seemed the best solution. It is helping us attract engineers; the people there are proving to be careful workers; we advanced our moving schedule when we found qualified production people at Fort Lauderdale. The uninterrupted pleasant weather enabled the builder to put up the plant quickly. There have been no delays in its construction.

Frank H. Rockett,
Director of Advertising
Airpax Products Co.

Seeks special course in switching

TO THE EDITOR—

In the May 1957 issue of CONTROL ENGINEERING is an article, "Static Switching Devices". Under the paragraph, "Useful System Design Hints", page 93, it is mentioned that certain companies have special courses to teach engineers the use of the static switching systems.

If you are able to supply the information that will enable me to contact the companies that offer this service, will you please do so.

H. W. Reynolds
Technical Center
Weyerhaeuser Timber Co.
Longview, Wash.

Westinghouse has conducted a half-dozen courses covering the uses of solid-state switching devices since the Fall of '55. The next one is scheduled for the last week of September '57. The fee will be $100, including room and board. Contact J. F. Captain, Sales Dept., Director Systems Div., Westinghouse, 356 Collins Ave., Pittsburgh, Pa., for more information. Ed.

HERE IT IS!

NMR

ANALYZER

Accurate moisture tests IN SECONDS...not hours ...with Schlumberger NMR Analyzer

H_2O measured through nuclear resonance of Hydrogen content . . . normal readings in ½ minute; accurate to .1%!

The new Schlumberger *Nuclear Magnetic Resonance* (NMR) Analyzer, uses principles of nuclear physics to measure the total H_2O (moisture) content of the material being tested . . . with speed and accuracy that present accepted methods can not approach.

Using the NMR Analyzer is remarkably swift and simple. The sample of material, enclosed "as is" in a sealed bottle, is placed in the test chamber and the scanning current switched on. The actual measurement is entirely automatic—the recording of the moisture content is inscribed on the moving chart that forms a permanent record.

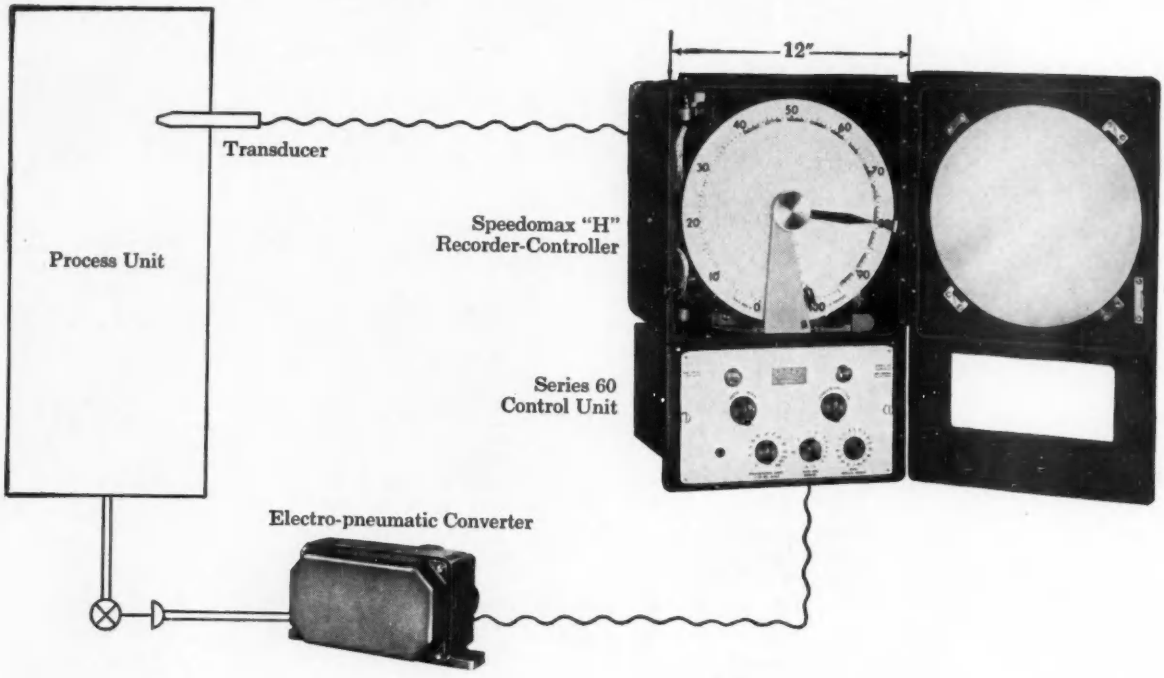
The Schlumberger Analyzer is virtually foolproof after being set up. Tests are made simply by placing the sample in the testing receptacle and snapping on the scan switch. Thirty seconds is the normal recording time, although in some instances longer periods are required —never exceeding four minutes.

Its effectiveness has been proved through field use on materials such as starch, paper pulp, grain, candies, syrups, cotton, etc.

If you would like to learn how the NMR Analyzer will perform on *your* materials, we will be glad to run NMR tests on your samples. Please write for information on the preparation and packing of your samples. For technical data on the NMR Analyzer, address
Applications Group, Room 200,
Schlumberger Well Surveying Corporation,
Ridgefield, Connecticut.

SCHLUMBERGER

WELL SURVEYING CORPORATION



L&N'S NEW C.A.T. ELECTRO-PNEUMATIC CONTROL

gives you these advantages:

- **FAST ELECTRICAL RESPONSE in measurement, control, transmission.**
- **SIMPLICITY, LOW COST, ADAPTABILITY and the special safety of pneumatic operation.**
- **EASY INSTALLATION with only 1 pair of leadwires from the control unit to the converter mounted near the process; then short air lines from converter to valve.**

L&N's C. A. T. (Current-adjusting type) Control combines the advantages of pneumatic valve operation with the flexibility and fast response of an electrical control system. The electrical signal produced by a change in the process variable passes from transducer, to Speedomax recorder, to L&N Control Unit. Here, the properly tuned combination of proportional, rate, and reset actions produces a control current which is fed to the Electro-pneumatic Converter. The Converter matches the control characteristics of the current output with an air pressure which operates the pneumatic valve.

The L&N Control Unit and all of its replacement parts are "plug-in" type for fast, easy servicing. The Unit's proportional band is adjustable from 0 to 500% of recorder range, rate time is continuously adjustable from 0 to 8 minutes, and reset action runs from 0 to 100 repeats per minute.

The force-balance type Electro-pneumatic Converter is ideal for installation directly on the process unit. It can be mounted anywhere, in any position; is vibration-resistant and weather-proof. Its minute (5 milliamp) current and continuous air purge provide a wide safety margin for operation in hazardous areas. If power fails or the control unit is removed, the control valve is sealed in its last position. And the Converter is so sensitive that its dead band is less than 0.1%.

C. A. T. Electro-pneumatic Control may well be the answer to your control needs. For details, write for Folder ND4(8). The address—Leeds & Northrup Co., 4918 Stenton Ave., Phila. 44, Pa.

LEEDS *instruments* **NORTHRUP** *automatic controls • furnaces*

RALPH J. KOCHENBURGER **bridges the gap**

At Storrs, Conn., there's a heady program under way to build an engineering reputation for the University of Connecticut, better known for its agricultural school than its engineering courses. One of the builders is Ralph John Kochenburger, who, as professor of electrical engineering, has shaped a first-rate graduate curriculum with a major area in control engineering.

When Kochenburger moved to Storrs seven years ago to set up a new graduate program in EE, the first thing he did was to study the state's industry. And after noting the concentration of machine tool firms, aircraft companies, and shipyards, he happily concluded that his own specialty, control engineering, was the field of electrical engineering that could make the biggest contribution to this industry. To this conclusion he added a concept learned at MIT—a good graduate curriculum has to be intimately tied to faculty research. The combination has been the key to University of Connecticut's growth in control engineering.

You might expect that research and teaching would be mainstays of Kochenburger's philosophy, because Ralph received what many people feel is the "classical" education for a control engineer: college, industry, doctorate. It started in 1936 when he enrolled in electrical engineering at MIT. As a sophomore he met Gordon Brown, MIT's ubiquitous professor of electrical engineering, who fired him with an interest in servomechanisms. From this it was a short step to an interest in overall control and instrumentation. His BSEE in 1940 was followed by an MSEE degree from MIT in 1941. Then he joined Curtiss-Wright's Propeller Div. as a research engineer. By 1946 he had become director of the Analytic Group, and he had received a patent for noninteracting controls on a turbo-prop-engine—a concept that has been widely used since by Curtiss-Wright.

In 1946, Kochenburger returned to MIT's Servo Lab to study for his doctorate. In his thesis, he introduced the use of describing-function theory for handling nonlinear systems in general.

After receiving his ScD in 1949, Kochenburger accepted the challenge to build a new graduate program at the University of Connecticut. In 1951 he was promoted to associate professor, and a year later was raised to his present rank of full professor.

Teaching graduate courses and consulting are inseparable, according to Kochenburger. As he sees it, "Consulting is really teaching. To explain to somebody how to solve a problem—the consultant's job—you have to be a teacher." And he adds, "By teaching and consulting, you can keep an overall view of what's going on in the whole field; that's a must for first-rate graduate-level instruction."

The variety of subjects that he studies as teacher and consultant is the chief attraction of his job at U. of Conn., he says. One week he's working on an electronics project, the next it's the control of an industrial process without a single electronic device. Over the past ten years Kochenburger has served as a consultant to a number of control, aircraft, and computer manufacturers. He intends to apply this broad experience to the new book he's writing on feedback control systems. "If I had specialized in only one industry, I would never have been able to start this book," he muses. At the same time, Kochenburger thinks that consulting is good for the teaching part of his job. He feels that "a lot of people who are teaching engineering never get the chance to practice it."

As a consultant, Kochenburger feels his forte is bringing together the theoretical analyst and the gadgeteer. Ralph sees a distinct gap existing between the so-called practical engineer and the theoretician. In some cases, neither can see the other's viewpoint. For, on one hand, a day of analysis sometimes can provide the answer to a problem that a month of gadgeteering wouldn't budge. And on the other, there are some things that either can't be analyzed or would take too many people too long.

Astounding

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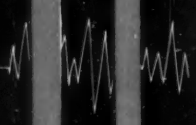

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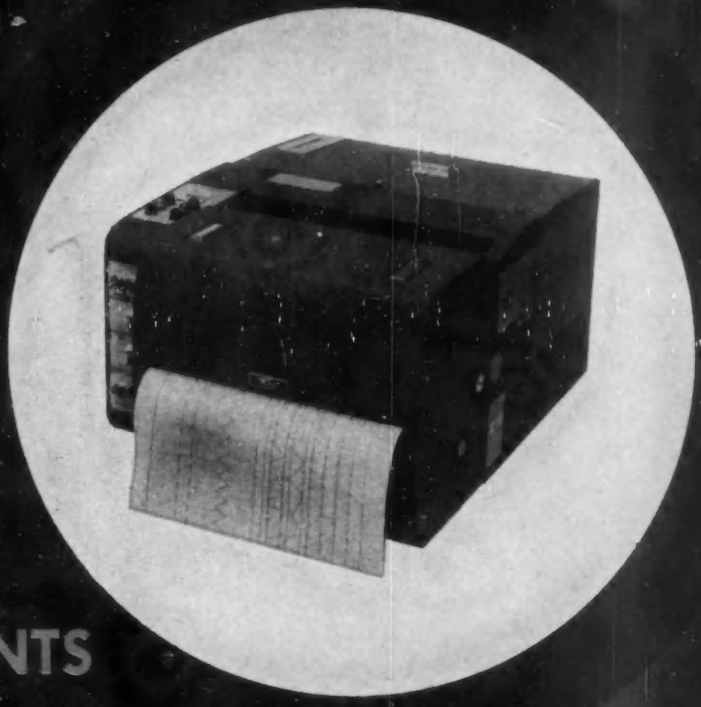
MAGAZINE CAPACITY	Model 601—150 feet Model 602—200 feet
RECORD SPEED RANGE	0.0812 to 129.9 inches per second
FREQUENCY	dc to above 3,000 cps
WRITING SPEED	Above 30,000 inches per second
OPTICAL ARM	11 inches
POWER REQUIREMENTS	110 volts—60 cps
TIMING LINES	0.01 and or 0.10 second intervals
SIZE	Model 601—11 1/16" x 11 9/16" x 23" Model 602—11 1/16" x 16 13/16" x 24 1/2"
WEIGHT	Model 601— 90 pounds Model 602—130 pounds



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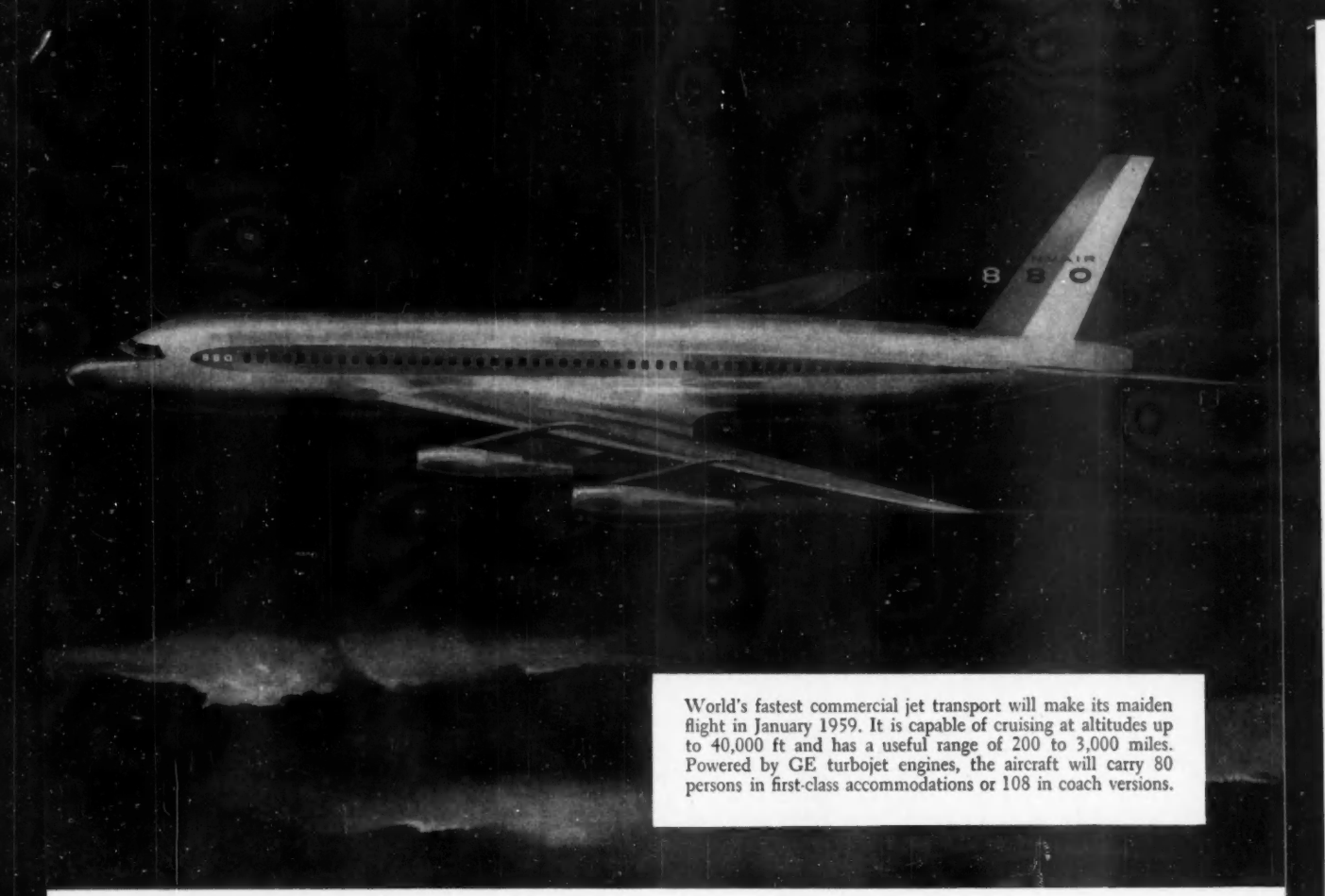


World's fastest commercial jet transport will make its maiden flight in January 1959. It is capable of cruising at altitudes up to 40,000 ft and has a useful range of 200 to 3,000 miles. Powered by GE turbojet engines, the aircraft will carry 80 persons in first-class accommodations or 108 in coach versions.

CONVAIR 880

Safety Dictates Duplicate Controls

First report on control systems of the Convair jet liner shows safety is the prime factor in design. Proof: complete fail-safe control systems throughout, with duplication of all primary linkages and mechanisms.

Last month in San Diego, engineers put the finishing touches to a new control system for the world's fastest jet transport*, the 615-mph Convair 880. Most significant features:

- Fail-safe flight controls with duplicate primary systems and components
- Simplified cockpit arrangement
- Warning devices and interlocks to prevent "human" errors

The design indicates zealous concern for passenger safety in the new high-speed jet liners. Remembering the accidents and bad publicity surrounding the British Comets, the first jet commercial transports, Convair Div. of General Dynamics Corp. is bending over backwards to guarantee safety of flight in the 880.

According to Bob Ferguson, in charge of flight controls for commercial aircraft at Convair, one result of that concern was a complete single failure analysis on the 880's flight control system, proving that a single failure of any control mechanism would not interfere with aircraft guidance.

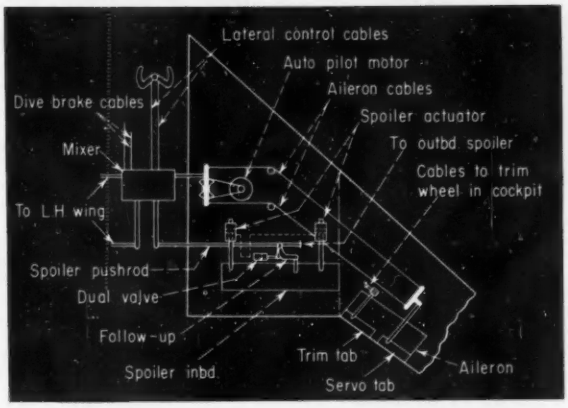
• **Pilot response**—In addition, for the first time the pilot was considered as an integral part of the control system. Convair control engineers, noting his capabilities and limitations, found that he has slow response time compared to operating mechanisms, and that this becomes a problem at the new high speeds.

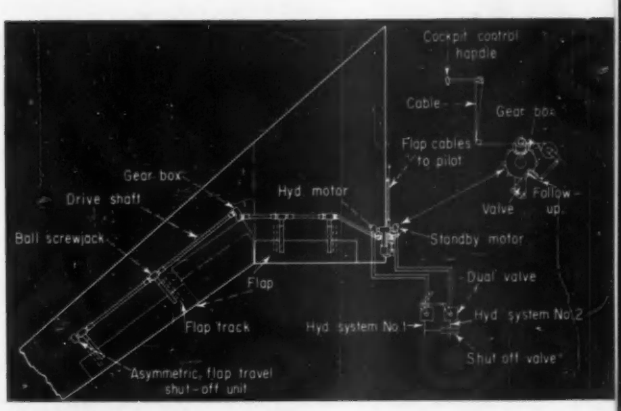
To help overcome this, many of the controls operate in closed loops instead of the open loops presently used on commerical aircraft. As a result the pilot can choose the amount of

* *Speed based on zero winds.*

LATERAL CONTROLS

System consists of manually operated ailerons and power operated spoilers which also can be used as speed brakes. Spoilers are controlled by closed loop which permits pilot to select braking.



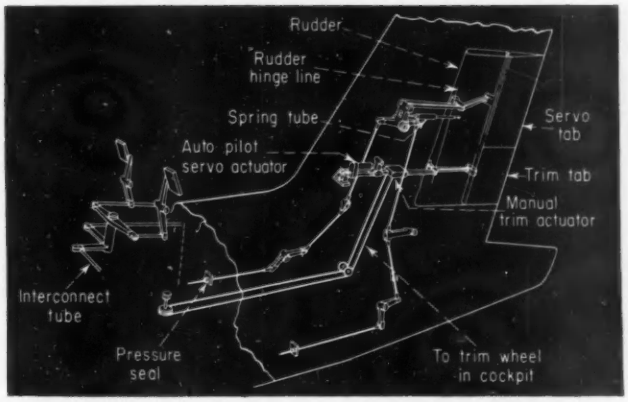


FLAP CONTROLS

Flaps are driven by dual hydraulic motors, controlled by a metering valve mechanically connected to the control valve in the cockpit. This system also is a closed loop; flaps automatically follow position of the cockpit control.

RUDDER CONTROLS

Directional control system uses manually operated rudder and tab. The autopilot actuator operates the trim tab.



control he wants quickly. For example, flaps (whose main function is to supply additional lift on take-off and additional drag on landing) are operated by a closed proportional loop control that permits the pilot to preselect the exact angle he wants by moving a control lever to a designated position.

The same system permits the pilot to set the flaps exactly at the optimum angle for take-off.

The flap-control system is rate-limited to provide automatically the proper change of position during take-off and landing. And there is a built-in monitor which prevents accidents by comparing both ends of the closed-loop system to make sure it is working correctly. If there's an error signal—flaps are not set as indicated—the automatic system is shut off.

Both elevator and lateral controls are also dual systems. Since there are two separate systems to control elevators and stabilizers, the pilot has four separate systems to control the pitch of the aircraft. In the lateral control system, the spoilers (which change rate of descent and climb by increasing or decreasing lift) are also operated by a closed-loop system.

• **Breaking devices**—Because of its normally high cruising speed, the 880 is equipped with three separate braking devices: 1) a speed brake, an innovation on commercial aircraft, which operates by reducing lift; 2) a conventional aircraft braking system, and 3) jet-reversing air flow.

The speed brake is operated by a closed proportional loop system which permits the pilot to choose the degree of braking imposed. The conventional braking system operates on all wheels and is completely dual for safety.

One of the most unique control systems reverses the air flow through the engine to help slow the plane down somewhat, like reversing the props on a propellor-driven airplane. The control is mechanically interlocked so that if, for some reason, the air flow in an engine is not reversed, it is impossible for the pilot to feed fuel to that engine.

• **Duplicate linkages**—Other safety features: 1) Linkages from both pilot's wheel and co-pilot's wheel are routed separately to operating mechanisms. In case of a failure in any linkage, one set of controls is still unaffected. 2) The tail can be moved mechanically with a hand wheel in an emergency; normally it is operated by the hydraulic system. 3) Landing gear can be lowered manually if the hydraulic system should fail.

• **Instruments simplified**—Another innovation in the Convair 880 is the instrument panel, which was "human engineered" to make meters easy to read and levers easy to reach. The pilot and co-pilot's panelboards have been simplified by reducing the number of indicators on each, limiting them to essentials concerned with flight. To do this, Convair transferred the responsibility for monitoring many variables to the flight engineer. Dials that

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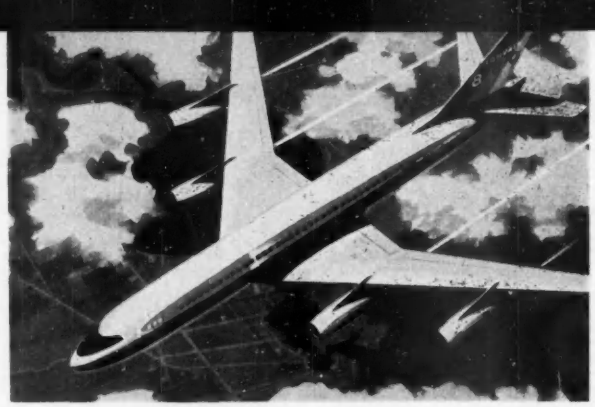


JET LINER . . .

STORY STARTS ON PAGE 22

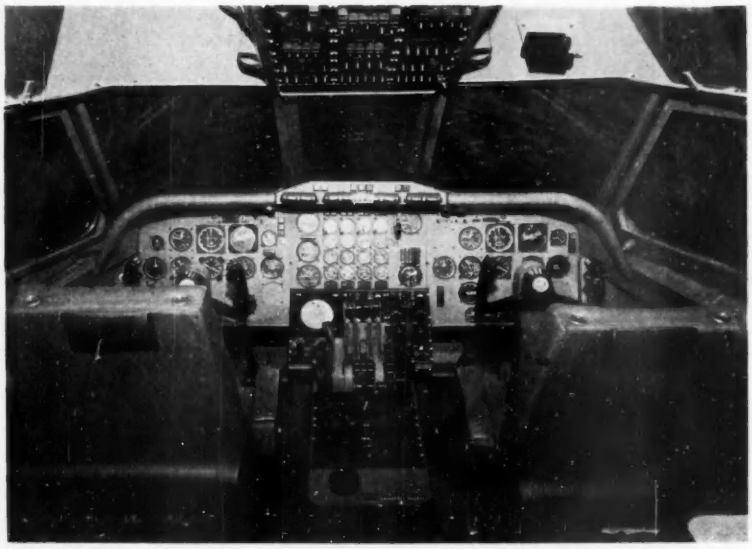
monitor systems, for instance, (such as temperatures for engines) have been moved to the flight engineer's panelboard and just a single master warning light is placed in front of the pilot.

Here's how it works in flight: If temperatures in No. 2 engine, for example, get too high, the warning light glows red on the pilot's instrument panel; a quick look over his shoulder at the engineer's board pinpoints the trouble, telling him what is wrong, where, and by how much.

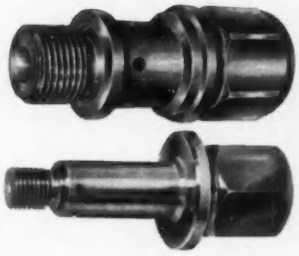
Instruments have been grouped according to function. Flight instruments are placed directly in front of the pilot and co-pilot (each has a complete set); engine controls are placed between them; and radar, auto-pilot, and communication equipment controls fit on a pedestal below the engine instruments. All instruments are edge-lighted to make them easy to read during night flights. The pilot will be able to maneuver through the auto-pilot. At least two autopilot systems will be engineered into the airplane.

• **Warning systems**—Throughout the design of the control system, Convair kept the concept that the pilot still must fly the airplane. To make his job easier, it supplied simpler controls, made them easier to see, and used closed loops. To keep the pilot advised that controls are working satisfactorily, there are built-in warnings on several systems. Example: an audio warning sounds if the pilot tries to take off with the flaps set at any angle but the optimum for take-off.

The overall result, say Convair control engineers, is the safest commercial plane they have ever designed. Both Trans World Airlines and Delta Air Lines have 880's on order, and the first flight is scheduled for 1959.



Human engineered cockpit simplifies pilot's panelboards by moving many monitoring instruments to engineer's board (not visible in this view).



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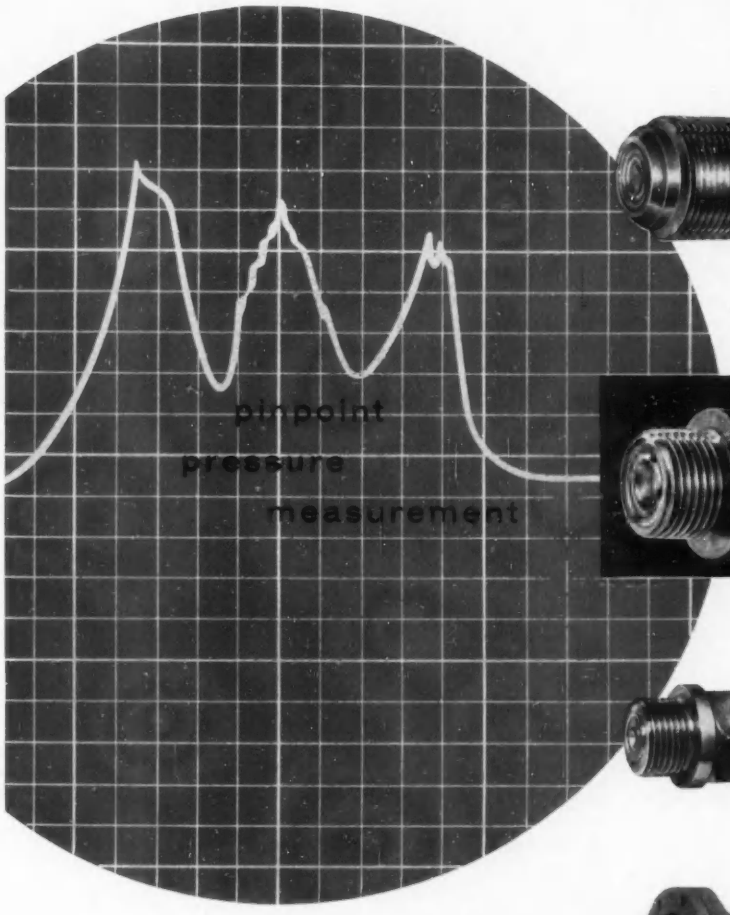
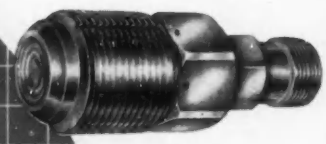
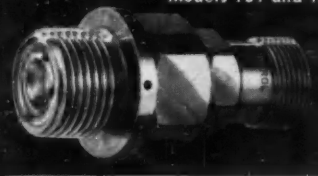




Model 104 Pressure Transducer

For high pressure applications in blast analyses, gun barrel pressures, hydraulic high pressures, etc. Frequency response: flat from 0-20,000 cps.

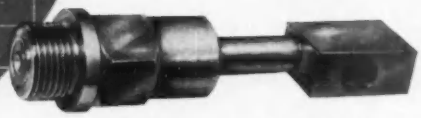
versatile



Models 101 and 102 Pressure Transducers

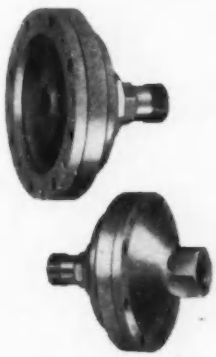
Highly accurate, versatile transducers for dynamic pressure measurements requiring high frequency response (flat from 0-20,000 cps). Ranges from 0-100 up to 15,000 psi.

rugged



Model 107 Pressure Transducer

Water-cooled, high frequency transducer for pressure studies under very high temperatures. Can be exposed to gas temperatures above 5000°F without damage. All welded construction for any applications, including highly corrosive liquids and propellants.



Models 105 and 106 Low Pressure Transducers

For pressure ranges 0-25 and 0-50 psig. Utilize same strain tube assembly as models above. May be used under conditions of extreme vibration as encountered in measuring shock waves in open air.

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DC Output Voltage	0-10	0-10	0-25
(three ranges)	0-25	0-25	0-50
	0-50	0-60	0-120
Output Current (amps.)	0-1.5	0-5	0-2.5
Regulation, line: 105-125 V	±1%	±0.5%	±0.5%
For wider input	±2%	±1.0%	±1%
Internal Resistance, typical (ohms)			
low-voltage range	1.2	0.35	1.3
middle range	2.1	0.55	2.0
high range	4.5	1.0	4.0
Ripple (mv)	50 max.	50 max.	50 max.
Time Constant (line)	0.08 sec.	0.08 sec.	0.08 sec.
(load)	0.15 sec.	0.15 sec.	0.15 sec.

MODEL T50-1.5

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The doctor's black bag hasn't seen a new instrument in 50 years, Dr. John Heller told top instrumentation specialists* as . . .

The Doctors Ask for Help

Sym'bi·o'sis, *n.* The living together in intimate association or even close union of two dissimilar organisms.
—*Webster's New Collegiate Dictionary*

How to get the medical profession and instrument engineers into symbiosis turned out to be the number one problem at the unique "Conceptual Clinic for New Instrumentation for Medicine and Biology", co-sponsored at Ridgefield, Conn., last June by the Foundation for Instrumentation, Education & Research and the New England Institute for Medical Research.

Doctors and engineers don't talk the same language, nor do they think the same, the conferees discovered during the day and a half of sometimes heated discussions. The conference was arranged to bring some of the problems of measurement and analysis faced by doctors to the attention of top physicists and engineers in instrumentation. But the gap between the two professions loomed more formidable than the problems.

A heated exchange during an after-dinner feedback session between MIT's Professor Norbert Weiner and Capt. C. P. Phoebus, USN Medical Corps, illustrated the trouble. Weiner had previously presented a description of "alpha-rhythm", a stable frequency which he has isolated by a wave analysis of electro-encephalograms. He predicated that the alpha-rhythm would give the medical profession a new physiological index, one of mental activity, to supplement blood pressure and pulse rate. It would be up to the medical profession, the MIT mathematician admonished, to correlate this index with physical well-being and sickness.

MIT's Norbert Weiner (left), FIER's Lloyd Slater (right).

• **Alpha rebuffed**—Not so, argued Dr. Phoebus. What the medical profession wants, he pointedly explained, are devices or instruments that give answers in diagnosis or an indication of diagnosis. He hinted broadly that he felt too much effort was spent on theoretical approaches and not enough on developing hardware to "give the doctor answers".

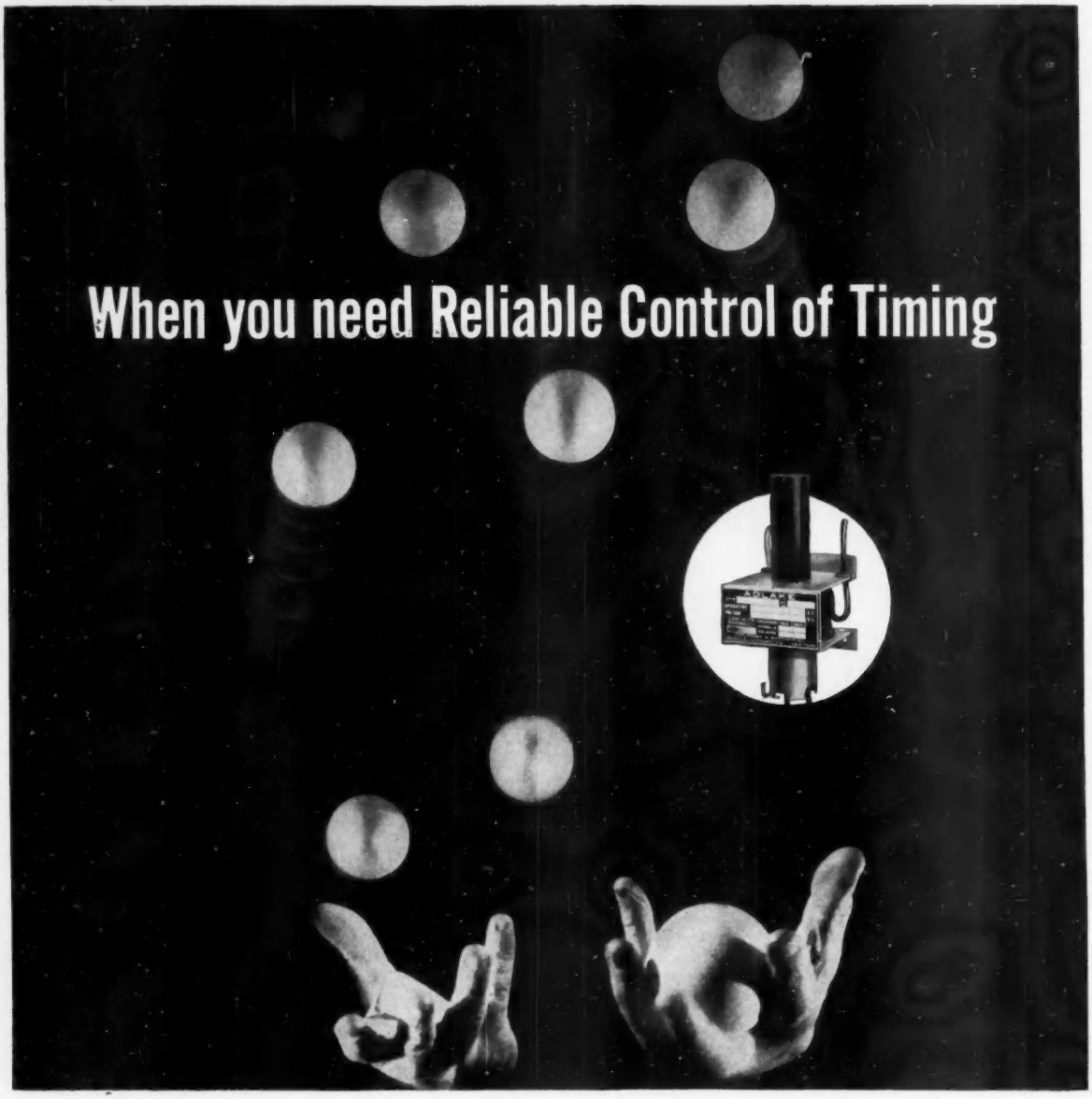
As this argument waxed hotter, Dr. John Heller, director of the New England Institute, interceded in an attempt to change the subject, but discussion turned right back to fields that emphasized a lack of symbiosis. Engineers insisted that many of the problems the doctors described could be solved with present-day technology if the doctors were willing to modify their thinking and use these new advancements in their studies.

• **One problem solved**—The next day's session provided some proof of this. Obstetrician Dr. I. Friedman posed this problem: how to measure an expectant mother's pelvic opening without subjecting her to heavy doses of x-rays. He had barely finished his description of the problem before suggestions came hurtling from every direction. One engineer came up with a pulse radar, another with a mechanical indicator, still a third suggested a magnetic technique that had been used for tracer purposes. It was the feeling of the clinic that there could be an instrument on the market to make this measurement—without x-ray—within two or three months.

But despite the undercurrents of antagonism, there was a genuine desire to correct the situation. One engineer summed it up during the heated evening session as, "We are all interested in doing something about this. How do we go about it?"

• **A follow-up**—That's where the ISA-sired foundation hopes to take over. Executive Director Lloyd Slater, encouraged by the interest expressed at the close of the session, plans a follow-up. As Slater pointed out, "It's obvious that a lot of the doctor's problems can be solved by technology the instrument engineer has now. This knowledge ought to be put to work saving lives."

Clinic attendees agreed that the best way to do this is to get instrument men and doctors working closely together. Just about everybody felt that the conceptual clinic was a good first step toward symbiosis.



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NEMA Makes a Change

Revised standards uprate two sizes of motor starters in first standard control changes in 20 years.

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	NEW	1	2	3	2	3	5
SIZE 1	OLD	1½	3	5	3	5	7½
	NEW	2	3	5	3	7½	10

In June, the Codes & Standards Committee of National Electrical Manufacturers Association met in Montreal to consider a proposal prepared by standard control manufacturers and already approved by various NEMA divisions. The committee's action: approval of revised NEMA Standards for Industrial Control.

This final green light culminated three years' work by manufacturers to bring motor-starter standards into tune with present technology, allowing them to take advantage of improvements in design and materials. Users, too, have made a lot of changes in motor applications since the present standards were adopted back in 1937. For example: the trend to replace one or two large motors with several small ones has made it harder for the designer to find space for all the motor control.

Major impact of the new standards will be felt by the Size 0 and Size 1 contactors and the various starters made from them. Other sizes are unchanged. The 8-hr rating for open starters has been dropped and only the continuous current rating for enclosed-starters is listed. For users, the major advantage will accrue from the hp upratings (see chart above).

All the changes affect motor control used for starting purposes only. Special ratings for plugging, jogging, etc., have not been changed.

Manufacturers of motor starters will swing over to the new standards as quickly as they can. Many had production plans all set, waiting the final approval from NEMA.

AIA Reports on Numerical Control Problems

After two years of intensive study, AIA's comprehensive report of the problems of numerical control has made its eagerly awaited appearance, just in time to beat first deliveries of numerically-controlled machine tools ordered for the USAF's big machine tool program. For many airframe manufacturers, the report—prepared by the Subcommittee on Numerical Control (SNC) of the Airframe Manufacturing Equipment Committee—will serve as a guide for their use of the new tools.

The 114-page booklet covers primarily AIA Class IV machines—continuous tool path control—because the committee felt that these machines have the biggest potential for production increases and cost reductions in the aircraft industry.

The first portion deals with nomenclature and definition of terms. It includes an attempt to standardize machine axis nomenclature for a variety of tools from lathes to profile millers. Another section reviews the complicated problem of programming, and then reports the results of a survey of users' programming plans. Typical highlights:

▶ Ten out of 14 plants replying anticipate using the same model general-purpose computer for computing primary machine tool input data.

▶ Thirteen plants indicate that they are willing to participate in a joint machine tool control computer programming group activity to interchange programming information.

▶ Seventy percent of all cuts to be performed were reported to be straight lines or circles.

▶ Eighty percent of the cuts are presently specified by stating end points and coordinate points.

From its survey, the subcommittee was able to make at least one encouraging conclusion: programming equipment will be sufficiently common to make a joint programming activity worthwhile.

• **Compatibility**—One of the most controversial areas covered is compatibility. The report breaks the problem down into four parts:

1. Raw storage—standardization is required since this information becomes the basic computer input.

2. Instruction storage—SNC feels this is RETMA's responsibility, and RETMA has issued preliminary standards for eight-hole, punched paper tape.

3. Position storage—for systems that have interpolators separate from

RAMBLINGS ON INSTRUMENTATION

Melvin Rides Again!

Our man Melvin, one of Hays' lovable service engineers, turns in call reports that occasionally border on the supernatural. However, he invariably sticks to the facts when talking about Hays products. Which is all we'll vouch for in his latest report. Here it is:

HAPPY HARBOR MOTEL
Happy Harbor, Michigan

Dear Captain Bligh:

Due to a series of circumstances that would shrivel a lesser man, I am temporarily detained in this dreary outpost on Route 117A. I received your rather stiffly worded wire yesterday and gather there has been some question as to my whereabouts. I'm sure that when I tell you what I've been doing, you'll agree that old Melvin has been hitting the old ball for Hays as hard as ever.

As you know I came up here to take delivery on my new car and it occurred to me that I might check up on a few of the many Hays installations here in the Motor City (figuring the company would be glad to take care of the few additional expenses involved).

One of our Electronic Mercuryless Flow Meters has been in service in a foundry of one of the Big Three auto companies for some time and I dropped over to see how it was operating. If I were you, I'd keep the following information under wraps because if our engineering department gets wind of it they'll want a raise en masse.

Seems the foundry uses this instrument for measuring oxygen flow in a scarfing operation, a process for cutting scale off forgings with an oxy-acetylene torch.

So far as maintained accuracy over a long period of time is concerned, the folks in this foundry rank their Hays meter right after the sun and the moon. Get this . . . after two full years of service there have been no tubes changed in the amplifier, no change in the original calibration as shown by the water column calibration check they give it every three months, and it has never exceeded one percent in integrator error when compared with planimeter checks of the chart.

On the performance of this one meter, this mammouth outfit is specifying Hays meters . . . period. Nine more flow meters and remote indicating receivers have been ordered this month. More to come.

Not wishing to bother a busy executive like yourself with trivia, I am enclosing my expense account in what you might call broad, outline form. I'm sure you'll agree the expense is well justified, even though this was not, strictly speaking, a business trip.

Matter of fact, I'd appreciate it if you could have a modest advance wired to me here at Happy Harbor so I can ransom my luggage from the curmudgeon who runs this air conditioned cell block. Apparently he's never heard of credit cards!

Urgently yours,
Melvin

More on the Universal Recorder

In last month's Ramblings we "leaked" some advance information on the new Hays Universal Recorder in an attempt to whet your appetite for same. Now it can be told that this surprisingly versatile instrument will be unveiled at the ISA show in September.

If you're the type that lies awake nights thinking about The Ideal Recorder (and who doesn't ?), this sleek new Hays product may enable you to get more sleep. Try to visualize an instrument of four quadrant construction with the following combinations of receivers:

4 Slidewires—resistance or potentiometer type with 2 alarm switches and 1 retransmitting slidewire;

4 Differential transformers — Hays-design 3-wire system with 3 limit switches and 2 retransmitting slidewires;

2 Integrators—continuous mechanical type; or . . . 4 direct actuated pens —pressure or temperature (2 per quadrant).

A possible one-instrument combination might be a steam flow pen with 2 alarm switches and a slidewire for remote indication, the steam flow integrator, an oxygen record with 2 alarm switches, a steam pressure pen, and a flue gas temperature pen. It also makes an excellent egg timer.

Sound interesting ? Wait'll you see it!

Phil Sprague Jr.
President

THE HAYS CORPORATION • MICHIGAN CITY, INDIANA

WHAT'S NEW

the computer, RETMA has also proposed eight-hole, punched paper tape.

4. Path storage—AIA still feels magnetic tape is best here. It proposes 14-channel, 1-in.-wide tape, using pulses as signals.

The subcommittee also reports the results of a detailed survey of numerical control systems. The makers, identified just by an arbitrary letter, were asked to supply information on 16 separate areas, including such fields as general data processing, construction, maintenance, etc.

• **Future plans**—One of the most interesting parts of the report is a glimpse at future plans of the AIA subcommittee. Eleven activities are listed, including:

- ▶ Comprehensive systems performance tests
- ▶ Establishment of compatible link standards
- ▶ Data processing and training requirements
- ▶ Computer subroutines
- ▶ Evaluation of numerically-controlled class IV machines in productive use.
- ▶ Evaluation of Class I, II, and III numerical control systems

For future users there was another optimistic note: SNC found that large numerically controlled machines cost slightly less than the same machine with a one-to-one table ratio tracer control. For those interested, a limited number of copies of the report is available from AIA's Washington headquarters.

DDA Council Formed

It's been less than ten years since the concept of the differential digital analyzer was first propounded at Northrup Aircraft. But since then, interest has been growing by leaps and bounds. Now, there's a specialized technical group for those who are working with these special-purpose computers.

Formal existence of the DDA Council, Inc., was announced in June, after several months of informal bimonthly meetings. Although the group confined these meetings to the southern part of California, it plans to extend its activities to other parts of the United States. New York was the site of a June 11 meeting.

Chairman is Stanley Rogers, Convair. Directors include: Max Palevsky, Packard-Bell Computer Corp.; R. G. Selfridge, Naval Ordnance Test Station; V. A. van Praag, Bendix Computer; A. L. Wolff, Litton Industries.

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Detects AC signals down to low amplitude levels, converts to 0—5 volt DC signal proportional to frequency within .2%, gives .25% long term stability with less than .002% per degree temperature coefficient.

MODEL FR-303

Compares power frequency with internal tuning fork reference, gives 0—5 volts DC between 370 and 430 cps, with .05% overall accuracy under severe vibration and temperature conditions.

20 standard modifications of the FR-300 series converters are available to suit every airborne and ground requirement.

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Solion Shows Promise

New electrochemical transducer (in right hand of NOL's Nelson Estes) boasts high sensitivity, accuracy, and low power requirements. Naval Ordnance Lab sees a variety of applications.

Physicists at the Naval Ordnance Laboratory, Silver Spring, Md. are predicting a bright future for a newly developed electrochemical device called the Solion (for ions in solution). Relying on the movement of electrons through a fluid (compared to vacuum tubes in which electrons move through gases, and to transistors in which they move through solids), Solion exhibits a sharp sensitivity to stimulus by temperature, pressure, light, sound, or acceleration.

Here is how it works. A special low-voltage dry cell battery initially excites a current in the Solion by moving ions between electrodes in an iodine solution. The current is sustained and varied by stimulation of the Solion by outside factors (such as temperature, pressure, light, etc.). A Solion requires very low power.

NOL physicists are convinced that the controlled movement of ions in solution will prove more effective than their controlled movement in space (vacuum tubes) or in solids transistors). They envision smaller, less expensive, and simpler instrumentation. And they predict far less complex circuitry when the new devices are used instead of vacuum tubes or transistors.

Uses have already been staked out in applications ranging from inertial guidance systems for missiles and aircraft to commercial products such as burglar and fire alarms, pressure indicators, and temperature indicators—products that operate with maximum speed and accuracy.

One application that has stirred the interest of Nelson N. Estes, who heads up much of the Solion developmental work at NOL, is an electrochemical integrator which may bring about a revolutionary reduction in the size, weight, and cost of air navigational equipment. Estes says the Solion integrator is about the size of a demitasse coffee cup.

The Air Force is testing an application of the Solion in an exposure meter to protect personnel against the low-frequency sound of jet engines, which can cause deafness. The sound meter, powered by a small dry battery, can be clipped to a mechanic's coveralls the same way a dosimeter is worn.

Still another application is the "Derry", an electrochemical derivative unit that can replace less sensitive thermostats in heating plant controls.

With potential applications clearly defined, the next problem with Solions appears to be production. Right now, there's only one manufacturer, Emhart Mfg. Co. in Hartford, Conn. Although the Navy says that "Solions are easy to manufacture", Emhart doesn't agree. Emhart's production is still only a trickle and the company blames such tough manufacturing difficulties as keeping contaminants out of the devices and holding the dimensions of plastic parts to 0.0001 in.

It's still too early to determine how much the Solions cost, but with production counted in handfuls, they would naturally come very high. However, NOL physicists think that the price can be brought down so that eventually Solions will cost less than equivalent transistors or vacuum tubes.

How to take an entire laboratory for a ride

Get complete mobile data despite shock and limits of space

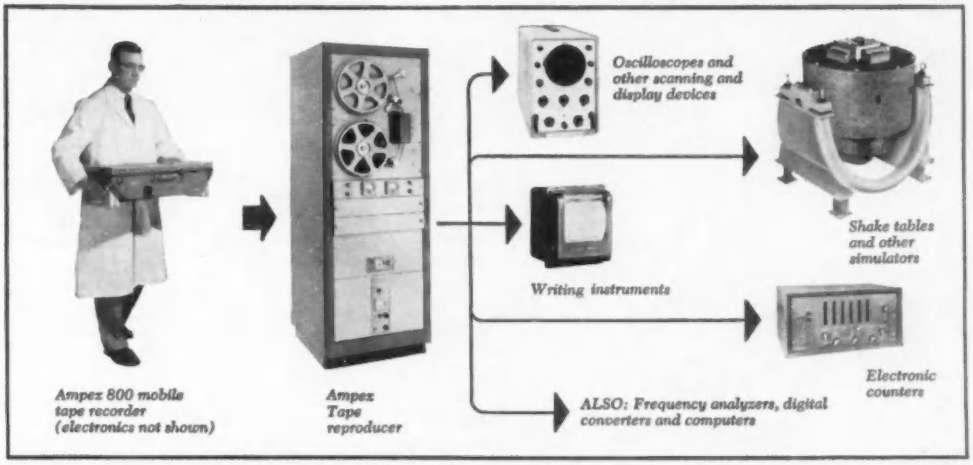
This is the easy way – no such blue-sky dream as a shock-mounted, air-conditioned brick building on wings or wheels. The earthbound laboratory has a "double" that rides on airplanes, vehicles or ships or goes to location by manpower, muleback or dolly. The secret . . . an Ampex 800 mobile tape recorder which simultaneously gathers data for the laboratory's writing, viewing, simulating and computing instruments. Despite adverse environment, Ampex 800s closely match precision and versatility of laboratory tape recorders.

AIRBORNE APPLICATIONS

Ampex 800s are widely used for environmental data, radio signals, radiation information, weapon countermeasures, flight parameters, etc.

At one airforce facility, the Ampex 800 rides in one aircraft to record telemetered signals from another (unmanned). Altitude greatly extends the horizon and tracking distance over which line-of-sight telemetered signals can be received.

Aircraft companies are tape recording vibrations, sounds, and other data far outside the range of other recording techniques. And in one major company's flight-test program, 420 channels of data are multiplexed onto a one-inch tape.


Oscilloscopes and other scanning and display devices
Shake tables and other simulators
Writing instruments
Electronic counters
Ampex 800 mobile tape recorder (electronics not shown)
Ampex Tape reproducer
ALSO: Frequency analyzers, digital converters and computers

Only this mobile tape recorder and its associated equipment undergo the hazards and space limitations of the mobile test situation.

Reproduction of the tape recreates the original transducer voltage patterns, providing every other laboratory instrument with the same input it would have received if it too had been carried on the test. Data slowdown, speed-up, filtering, etc. can be used.

Ampex 800 tape transport, showing small size and ease of handling. This is the largest of the recorder components.

GROUND, SHIPBOARD AND VEHICLE USE

The Ampex 800 is light and rugged, withstands handling and sets up quickly and easily. A research group studying earth-transmitted shock waves carries the Ampex 800 right to locations next to railroad tracks, airfields, highways and other areas of interest. An oil company uses a truck-mounted 800 to log oilwells in the fields.

The equipment stands shock, vibration and noise. In a shipboard installation, the Ampex 800 gathers data on closeby underwater explosions, enduring shocks transmitted through the ship. At an eastern jet-engine test facility, dolly-mounted Ampex 800s are wheeled out to the cells and get accurate data in an area of intense noise.

Do you have a mobile data acquisition problem on which we can help? Or would you like this tape-recording series mailed to you direct? For either request, write Dept. HH-6.

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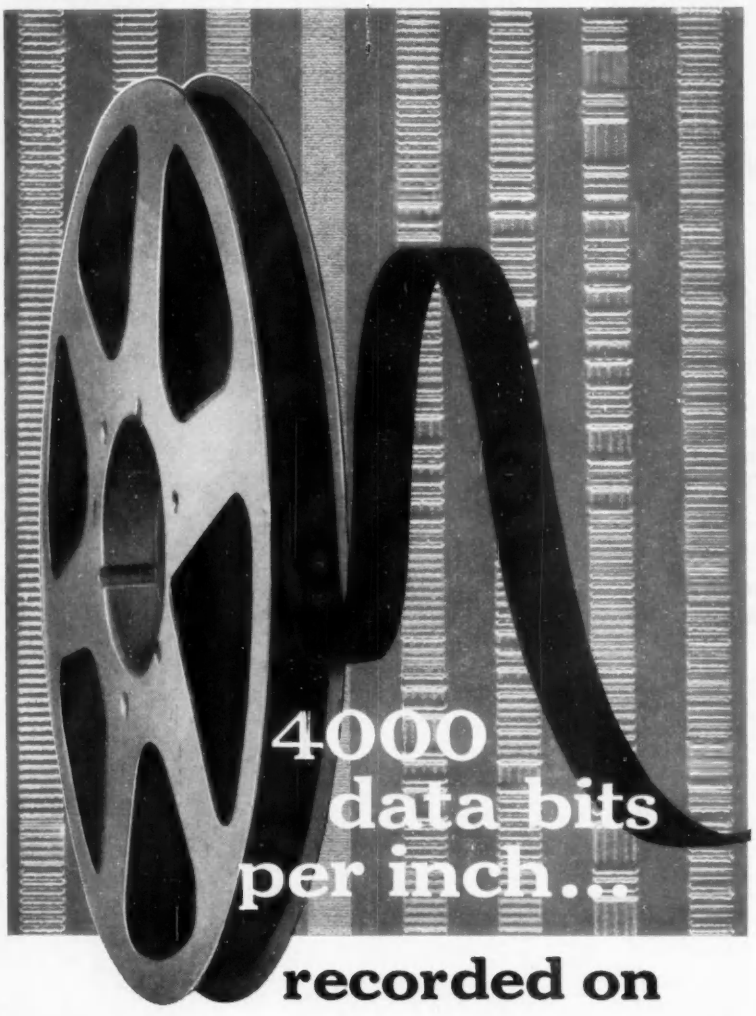
MAGNETIC TAPE APPLICATIONS BY AMPEX

6

Microphotograph of pulse recording on Soundcraft Instrumentation Tape



recorded on

SOUNDCRAFT type "A" INSTRUMENTATION TAPE

and played back without error!

In the new Rocketdyne IDIOT* II computer system, 4000 data bits (over 500 bits of information per channel, per linear inch) have been stored in an inch of Soundcraft Type "A" Instrumentation Tape... double the amount of information that has been stored in equivalent lengths of competitive tapes! What made the difference? Soundcraft Type "A" Tape ... the only tape engineered specifically for pulse recording. Its special RCCH oxide formulation provides an extremely hard surface with high thermal softening point – prevents imbedding of foreign particles. The formulation is uniformly applied to the durable Mylar† base by patented Uni-level process; then Micropolished to remove surface irregularities. These exclusive design features assure you of error-free pulse recording with Soundcraft Type "A" Instrumentation Tape. Write for Soundcraft Type "A" Instrumentation Tape Brochure.

*Rocketdyne Instrumentation Digital On-Line Transcriber. †Dupont T. M.

REEVES SOUNDCRAFT CORP.

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WHAT'S NEW

Transistor Logic for Computer Circuits

Leprechaun, no bigger than a TV set.

Compared to previous digital computer designs, Leprechaun,–newly developed at the Bell Telephone Laboratories–operates with drastically few components. Excluding its magnetic cores, it uses only about 9,000 components, 5,000 of which are transistors.

But the real innovation in this new high-speed digital computer is that it proves the feasibility of "direct coupled transistor logic", a circuitry technique in which transistors are called upon to perform logic operations as well as to provide power.

Developed under Air Force contract, Leprechaun is to be used for programming and logical design research on digital computers for military real-time control applications. Because it is a research model, its components can be easily connected and disconnected.

• **Memory features**–Another feature of the new computer is its transistor-driven "random-access magnetic core memory", organized to store 1,024 18-digit words. Access is provided by coincident-voltage magnetic core diode switches. Using a system of staggered read drive, a 20-microsec read-write cycle has been achieved.

For computer operation, word length determined by the control application is 17 binary digits, including sign. Except for this, Leprechaun is a general-purpose computer.

In logical organization, Leprechaun is parallel, and asynchronous, and all shifting registers and counters use the double-rank technique.

Expanded line of stock Sola transformers regulate filament loads up to 25 amperes

Sola Constant Voltage Filament Transformers are now available *from stock* in six different output ratings from 2.4 to 25 amperes. Now, even sizable banks of electron tubes may be supplied from one compact source of ±1% regulated filament voltage.

Because of the current-limiting characteristics of Sola transformer design, cold filament inrush current is restricted to a safe level at loadings within 75-100% of the transformer's full-load current rating.

The static-magnetic Sola filament transformer, furnished with separate capacitors, is designed for simple mounting as a component of manufacturers' products. The dependable tube performance and longer filament life these units offer is available at only a moderate increase in cost over conventional filament transformers.

For further information and specifications, contact your Sola representative, or write for Circular CVF-269.

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WHAT'S NEW

ISA Packs Program For Cleveland Meet

"Instrumentation for Systems Control" is the theme of ISA's 12th annual Instrument Automation Conference & Exhibit, which will open in Cleveland on Monday, Sept. 9, and run through the week to Friday, the 13. The program for the five-day conclave looks like a who's who in instrumentation management.

On the program Monday will be R. J. Jeffries, president-elect of ISA, John Johnston Jr., vice-president, ISA, and Simon Ramo, executive vice-president, The Ramo-Wooldridge Corp.

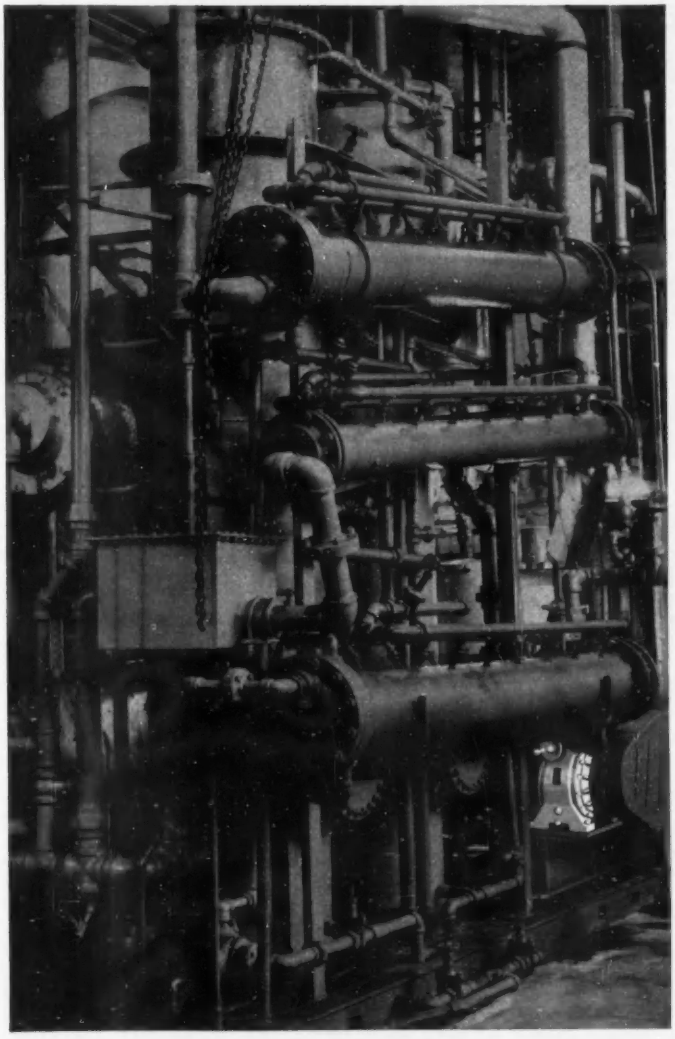
The Tuesday topic is "Research and Development View of Instrumentation for Systems Control". Speakers: Gordon S. Brown, MIT; John Hrones, Case Institute; Edwin L. Harder, Westinghouse Electric Corp. For the afternoon session: Van Zandt Williams, Perkin-Elmer Corp.; Forrest K. Harris, NBS; Donald Gimpel, Panellit, Inc.

Wednesday's meetings will focus on "The Performance and Application View of Instrumentation for Systems Controls". Cuthbert C. Hurd, vice-president of IBM, will keynote this session. Other papers will be presented by: Charles D. Close, president, CDC Control Services, Inc.; R. L. Moore, Case Institute; and W. A. Crawford, E. I. du Pont de Nemours & Co., Inc. Afternoon speakers scheduled: B. W. Thomas, Texas Butadiene & Chemical Corp.; Kermit Fischer, president, Fischer & Porter Co., and E. M. Grabbe, The Ramo-Wooldridge Corp.

The emphasis Thursday will be placed on "The Justification and Economic View of Instrumentation for Systems Control". Lt.-Gen. Donald Putt, deputy chief of staff, will keynote the presentation. Other speakers: Raymond E. Olson, president, Taylor Instrument Cos.; A. C. Brodie, Feedback Control, Inc.; Neil M. Blair, vice-president, Panellit Service Corp.; H. F. Moore, Esso Research & Engineering Co.; James MacDonald, Delaware Refinery, Tidewater Oil Co.; O. Glenn Saxon, Yale University.

The final day's sessions have been named "Over the Publishers' Shoulder on Instrumentation for Systems Control". Speakers: Gerald Piel, publisher, "*Scientific American*"; William E. Vannah, editor, CONTROL ENGINEERING; Richard Rimbach, publisher "*Instruments and Automation*", and Charles Covey, editor, "*ISA Journal*".

CLEVELAND SPEED VARIATOR
varies gas feed to annealing furnace need



THIS gas blower is part of the monogas system that feeds an annealing furnace. Rate of gas output from the blower is precisely controlled by a Cleveland variable speed drive.

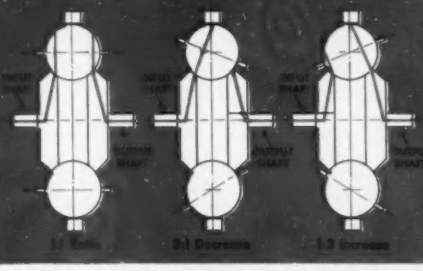
When the gas production rate must be decreased or increased to fit various annealing processes, it is easily regulated by a simple turn of the hand wheel on the drive. To maintain uniform supply of gas at all times, even if pump or compressor output varies, a simple adjustment on the Variator compensates and keeps the production rate steady.

This is one of hundreds of different applications of this unique Cleveland Speed Variator. Engineers and designers have put thousands of units into use on such diverse equipment as cigarette-making machines, textile machinery, metalworking machinery, pharmaceutical equipment, transfer tables, conveyors, testing equipment and experimental machines of many types.

Being infinitely variable, the Cleveland gives stepless speeds over a full 9:1 range—from ⅓ to 3 times input speed. Output speed on this particular application illustrated is adjusted by hand wheel, but could be regulated by either manual or automatic remote control. The Variator is available in 18 sizes, ranging from fractional to 16 hp at 1750 input rpm.

Write for Bulletin K-200 for detailed description with photographs, sectional drawings, rating tables and specifications.

HOW THE CLEVELAND SPEED VARIATOR WORKS



Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts.

Relative speeds of the shafts are adjusted by changing the positioning of axles on which the balls rotate (diagram, right, shows cutaway Variator with hand regulating wheel).

"It's the Drive That's on the Ball."

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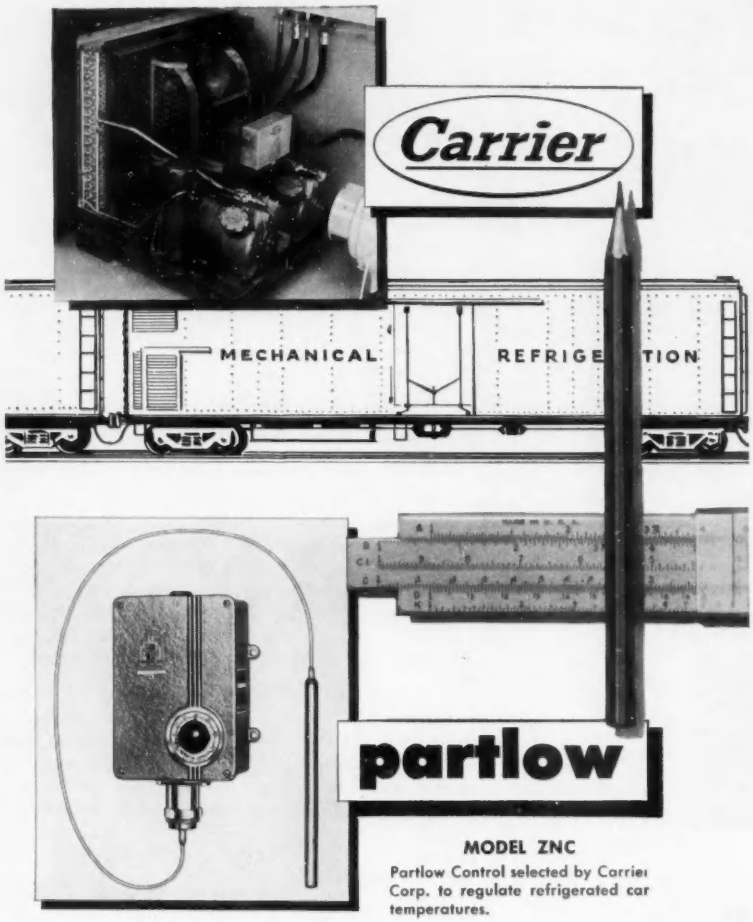

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Partlow Control selected by Carrier Corp. to regulate refrigerated car temperatures.

Partlow Controls help Carrier Railway Refrigeration Units "think for themselves"

Carrier Railway Refrigeration Units that "think for themselves" are setting a new standard for positive, controlled temperature in rail transportation of frozen foods. *And Partlow Controls call the signals that keep temperatures on the button!*

The Carrier systems are designed to heat as well as cool, providing a constant temperature despite the various climate changes encountered in transcontinental runs. A car temperature range from –10°F to 70°F is possible, depending on the Partlow Control setting.

What's your temperature control problem? Tell it to Partlow! There's a Partlow Control to fit your requirements . . . in the range from –30°F to 1200°F. For use with gas, oil, steam or water valves; or electrical equipment.

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WHAT'S NEW

CONTROL BITS

First fully automatic warehouse in California has been built by Gallo Sales Co., San Francisco distributor of Gallo Wines. Combination of conveyors, photo-electric cells, solenoids, and automatic counters permits fully automatic order-filling from a control console. Operator flicks one of 58 switches to indicate product desired; he pushes a second button to obtain proper quantity. As orders are "punched out", goods are automatically conveyed to delivery room.

•

Birmingham University (London, England) has announced a 12-month course in information engineering open to honor graduates of the university. The course, which leads to a master of science degree, covers the field of information theory as used in computers, control systems, and related fields of technology.

•

Robot tractor, automatically controlled from distances up to 15 miles, is being studied by the Army's Corps of Engineers at Fort Belvoir, Va. Equipment is a standard commercial "tournadozer", whose seat has been replaced by a military radio receiving set. Army engineers plan to mount a TV camera on the tractor to provide operator with "eyes".

•

GE will build a $4-million dollar materials testing reactor at its newly-dedicated Vallecitos Atomic Laboratory. Only other materials testing reactor announced by a private company is the one planned by Westinghouse. The GETR, which will produce 30,000-kw heat, will be used primarily to study the effects of nuclear radiation on materials and components.

•

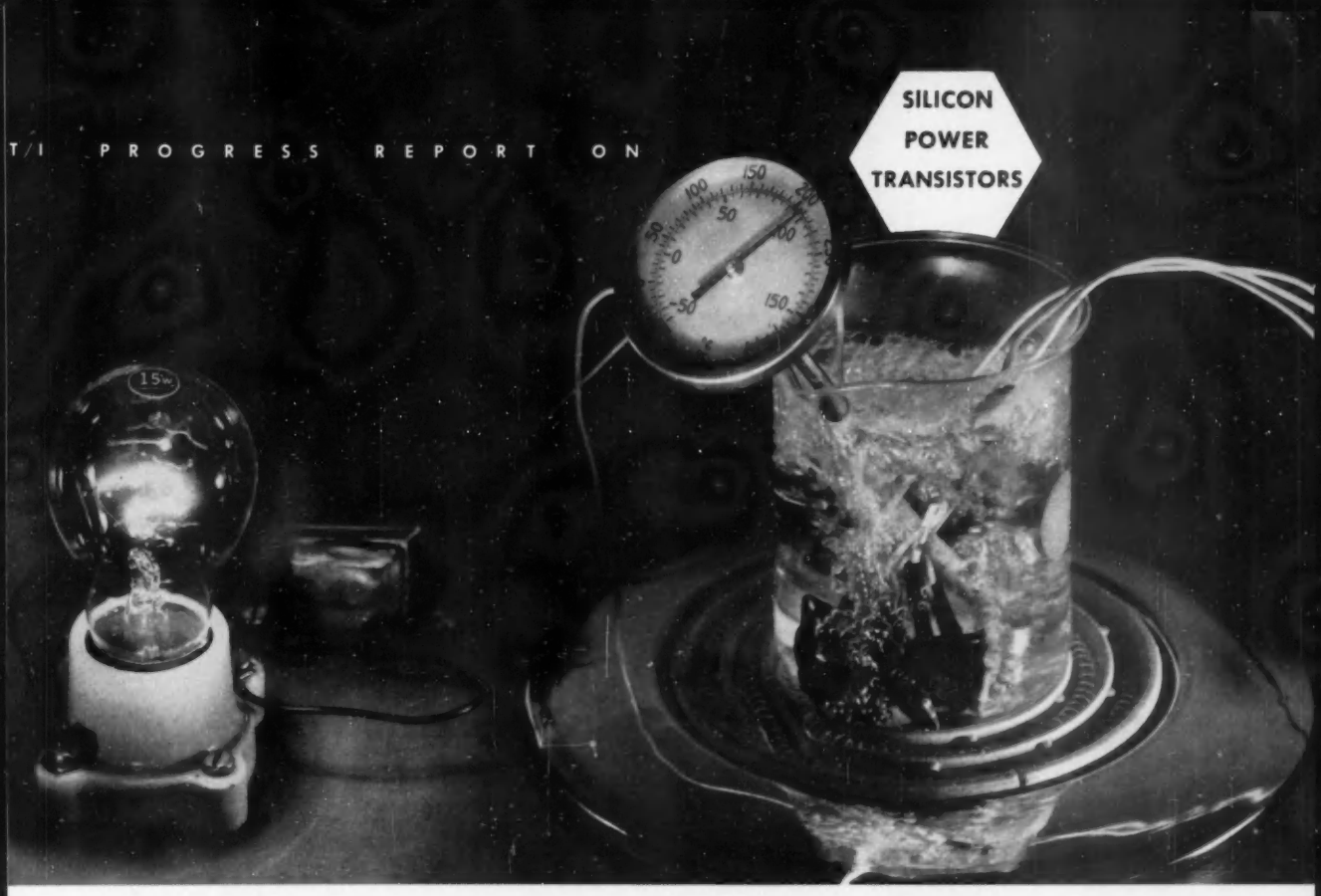
More students are preparing for engineering careers this year than at any time since 1948. U. S. Office of Education reports a total of 243,000 students in accredited engineering colleges last fall. The enrollment of seniors is up 20 percent over last year. Most popular field of study: electrical engineering.

•

Symposium on automatic control was sponsored by IRE Professional Group on Automatic Control in San Francisco, just before WESCON started. A morning session covered practical applications in nonlinear control; in the afternoon, a panel discussed obstacles to progress in nonlinear control.

T/I PROGRESS REPORT ON

SILICON POWER TRANSISTORS

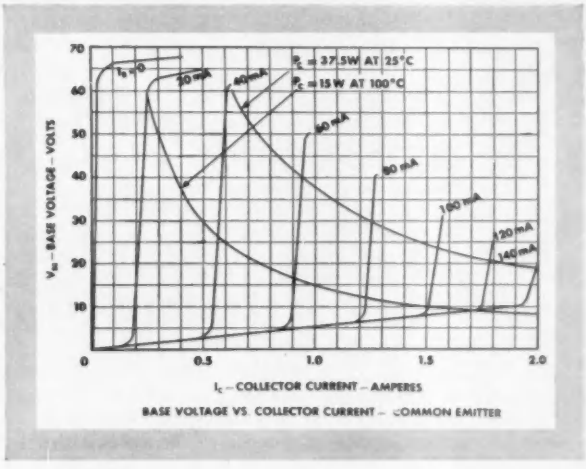


now you can get

15 watts at 100°C

NEW silicon high power transistor

For your audio servo uses – and many other applications, you can reach new transistor highs – in power, temperature and gain with low distortion and the stability and reliability you expect from silicon transistors. In Class B push-pull operation, two new TI Type 2N389 silicon diffused junction transistors provide 15 W power output at 100° C ... with distortion of less than 10% and typical beta cutoff frequency of 300 kcps. This new transistor is the first high power silicon transistor and the latest addition to the TI silicon line ... widest in the industry.



absolute maximum ratings

Power Dissipation at 100°C	15	Watts
25°C	37.5	Watts
Collector to Emitter Voltage	+60	Volts
Base to Emitter Voltage	−2	Volts
Collector Current	2	Amperes
Saturation Resistance	6	Ohms
Base Current	0.5	Ampere
Storage Temperature	−65 to +150°	C

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  0-5 to 0-5000 psi

to meet strictest requirements of

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an example of
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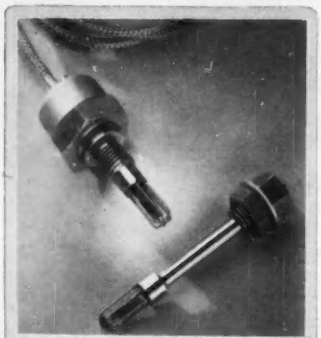
OPEN TEMPERATURE PICKUPS



The illustrated OPEN TEMPERATURE PICKUPS are precision platinum resistance thermometers capable of high-speed temperature measurement of gases and non-corrosive fluids. Resistance winding, supported on ceramic-insulated posts or on card, is in direct contact with environment to be measured, and can have time constants as fast as 50 milliseconds. Full-scale output voltages of 5 volts can be delivered directly to telemetry commutation circuits. Units operate over selected ranges from −320F to +750F (−200C to +400C), with accuracy better than ±1% of full scale and repeatability of ±0.2%. Calibration Certificate giving precise 5-point calibration supplied with each unit. Stainless steel case and rugged construction withstand 1500 psia pressures, ±25 g vibration, and 60 g shocks under MIL-E-5272A. Send for Technical Bulletins 1182 and 1350.

TRANS-SONICS
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BURLINGTON, MASSACHUSETTS

AROUND THE BUSINESS LOOP

Cohu Changes Kay Lab to Kin Tel, Then Absorbs It

Expansion, like charity, begins at home, and the expansion of Cohu Electronics, Inc., the new company recently formed by La Motte T. Cohu (CtE, June, p. 198) has begun with the absorption of Kin Tel of San Diego, Cohu-owned but heretofore not a corporate part. Kin Tel's proximity was not the only reason it was one of the first firms picked by the expanding Cohu organization, however: it also happens to have made money last year. As Kay Lab, it chalked up sales that went over the 1955 mark by more than 125 percent, or from $1,343,000 to $3,332,000. In the June story Cohu Electronics was located at San Diego, too. In the new corporate setup, however, the company gets a Deleware address and becomes an "eastern" firm. Said Cohu, speaking of the Kin Tel acquisition: "The action is in line with the company's expansion in the east and the contemplated absorption of other companies through mergers with Cohu Electronics. For these reasons it was considered advantageous to all shareholders to have an eastern corporation."

Several high-finance steps had to be taken to bring the changes about. First, Kay Lab's (or Kin Tel's) assets were sold to Cohu Electronics; second, Kay Lab received in return all the stock and assumed all the liabilities of Cohu; and third, Kay Lab was dissolved and the Cohu stock it had received was distributed to the shareholders. In this way each shareholder received the same proportionate interest in Cohu Electronics that he had had in Kay Lab.

One of the first personnel changes to be made in the new organization revolved around the position of vice-president in charge of engineering. The man who held this position in Kin Tel, Richard E. Langworthy, resigned and was succeeded by William S. Ivans Jr., formerly chief electronics engineer of Convair. Ivans, considered one of the foremost authorities in his field, steered many important Convair flight-control developments during his 11 years with that company. Before joining it, he was with the AF Aircraft Radiation Laboratory at Wright Field. Also well-known as a glider pilot, he holds two world altitude records.

Survey Shows $8.8 Billion Spent for R&D in 1956

Research and development work in 1956 cost $8.8 billion, says a Commonwealth Engineering Co. report appearing in the June issue of the company's organ, "Competition". How much of this amount can be claimed by control-engineering companies is not revealed, but clearly laid out are the contributions to the total by private-industry laboratories (about $7.2 billion), government labs (about $1 billion), and colleges and other institutions (about $0.6 billion). Sources for the survey are excellent: expenditures in the Federal budget, the National Science Foundation, and the McGraw-Hill Dept. of Economics. A projection through 1957 indicates, says Commonwealth's Chairman H. A. Toulmin Jr., an increase to $10.6 billion.

Philco, Gulton Establish Rental Plans for Products

Two prominent companies doing a big control-engineering business have established rental plans for some of their products. One is Philco Corp., which has set up an "overall sales financing program" involving such products as the Transac transistorized data processor, microwave communications systems, closed-circuit TV, the Exicon color x-ray viewing contrastor, and TV broadcasting equipment. The other company is Gulton Industries, Inc., which has put its ultrasonic systems and equipment on a rental basis.

Philco has this to say about its plan: "Although leasing of capital goods is a comparatively new type of industrial financing, business and industry are continually realizing the desirability of acquiring new capital goods by this method. Thus, funds ordinarily tied up in capital assets are released, earning capacity is increased, and a greater return is realized on the invested capital in the business."

Gulton has not as yet extended this marketing approach to its industrial control systems and automatic equipment, but expects to do so in the near future. It illustrates its plan with a small parts cleaner (console model) which sells for $3,000. On

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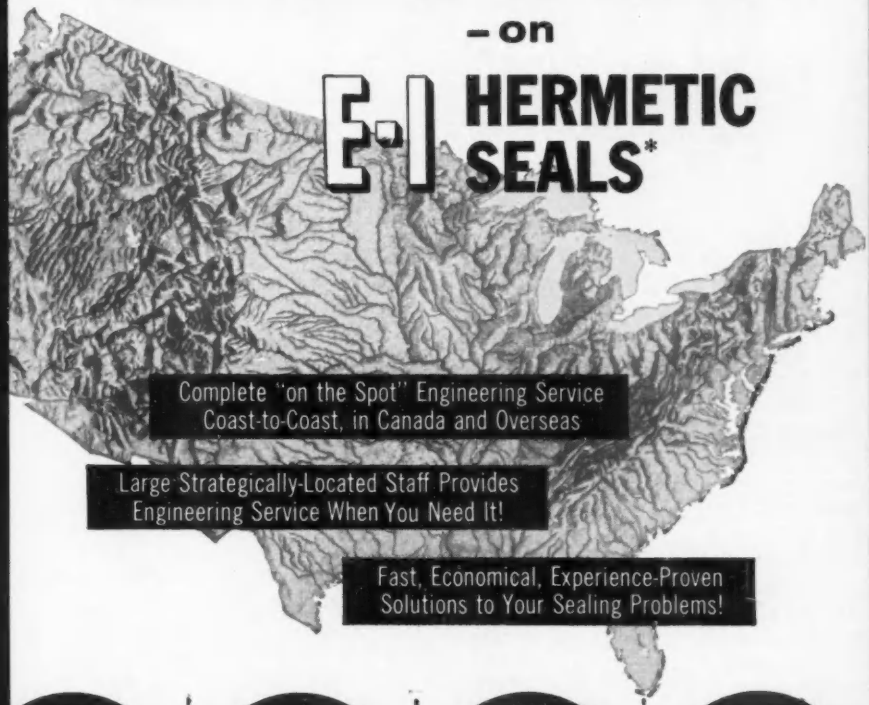

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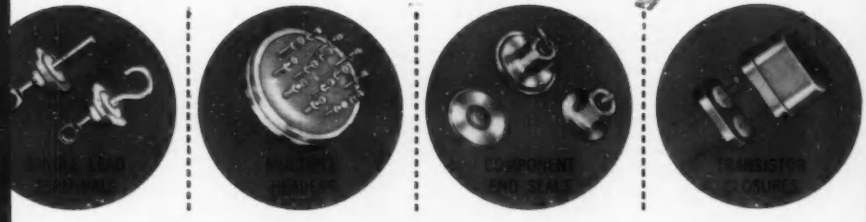

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POWER REQUIREMENTS: 4.5ma @ ±300 vdc, 0.6 amps. @ 6.3v	POWER REQUIREMENTS: 2.4 ma @ +300 vdc, 0.45 amps. @ 6.3 vac, 60 cps
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the rental plan, it would be available for $250 a month, including maintenance, parts repair, lifetime guarantee, and a service contract.

Cybernetics Association Grows, Plans an International Review

The Association Internationale de Cybernetique, formally organized in Namur, Belgium last Jan. 7, has set up a permanent secretariat at 13 Rue Basse-Marcelle, Namur. Georges R. Boulanger, president of the association and organizer of the first International Congress on Cybernetics, held at Namur in June 1956 (CtE, Oct. '56, p. 30), reports that the secretariat has received over 1,000 applications for membership from 26 countries. The association seeks individual and company memberships as well as direct contributions.

Boulanger defines cybernetics as "the science of behavior of animals and machines directed toward an objective" and says that it is possible to build useful animal behavior into machines. This science, he explains, covers man-machine systems, information display for easiest human recognition, and the social and economic aspects of automatic techniques. The association will publish the proceedings of the first International Congress and an International Cybernetics Review. Plans are progressing for an international conference this September on the social and economic aspects of automation and for a second International Congress on Cybernetics in September 1958.

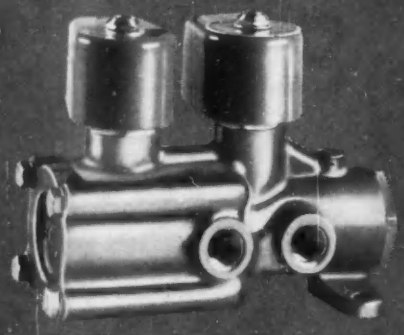
New Companies in the Field

Siegler Corp., the survivor of a three-way merger involving Unitronics Corp., The Hufford Corp., and Siegler—in Anaheim, Calif. President J. G. Brooks of Siegler sees a $75-million business coming out of the merger, with $50 million of this in electronics production. Clues to the girth of the new Siegler concern can be glimpsed in the names of the subsidiaries of the participating companies: David Bogen Co., Inc., Presto Recording Corp., and Olympic Radio & Television Co., all part of Unitronics; and Smith-Nelson Co. and Vac-U-Lift Co., both part of Hufford. Hufford's President Merrill L. Bengtson has been named chairman of Siegler's new executive committee.

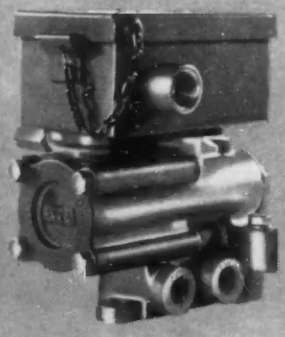
Semiconductors, Ltd., a joint venture of Philco Corp. and The Plessey Co., Ltd., of London, England, look-

Now available: full line of ASCO 4-way solenoid valves

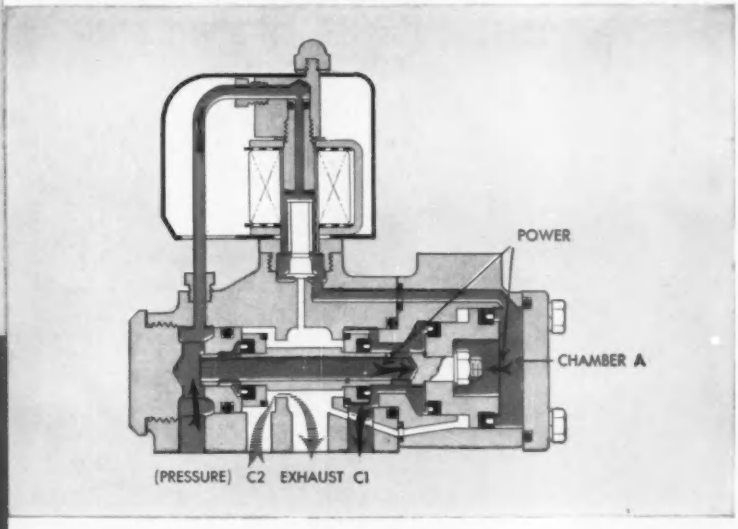
Single Solenoid: operates when solenoid is energized; returns automatically when de-energized.



Dual Solenoid: operates when either solenoid is energized; will not return until opposite solenoid is energized. Solenoids may be energized continuously or momentarily.



J.I.C. Construction: single and dual solenoids, with sub-plate mounting.



power driven in both directions by line pressure

Now available in ⅜" through 1" sizes, these valves are positive in action. When the solenoid is de-energized, *line pressure* applied to the top of the pilot core forces it off the seat, eliminating possible sticking caused by residual magnetism. *Line pressure* is applied to Chamber A, moving the piston-disc assembly to the left. When the solenoid is energized, Chamber A is exhausted and *line pressure* drives the piston to the right.

absolutely tight seating — no leakage

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J.I.C. construction available

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WHAT'S NEW

ing toward the manufacture of transistors and other semiconductors—in Great Britain. Also involved is Philco (Overseas) Ltd., which with the parent corporation will furnish technical knowledge and design information, and will supervise technical programs. Plessey, the largest electronic component manufacturer in the Isles, holds 51 percent of the 500,000 shares of stock in the new enterprise. Philco holds 49 percent.

Era Engineering, Inc., a consulting and R&D firm specializing in electronics, radiation, and rocketry—in Santa Monica, Calif. Already available from Era's laboratories are systems to: measure the distance between missile and target in a near-miss situation, measure erosion on missile surfaces under hypersonic environments, and mark the landing place of expired missiles. President David Shonerd, a long-time missile man, has been with Aerophysics Development Corp., Hughes Aircraft Co., and Caltech.

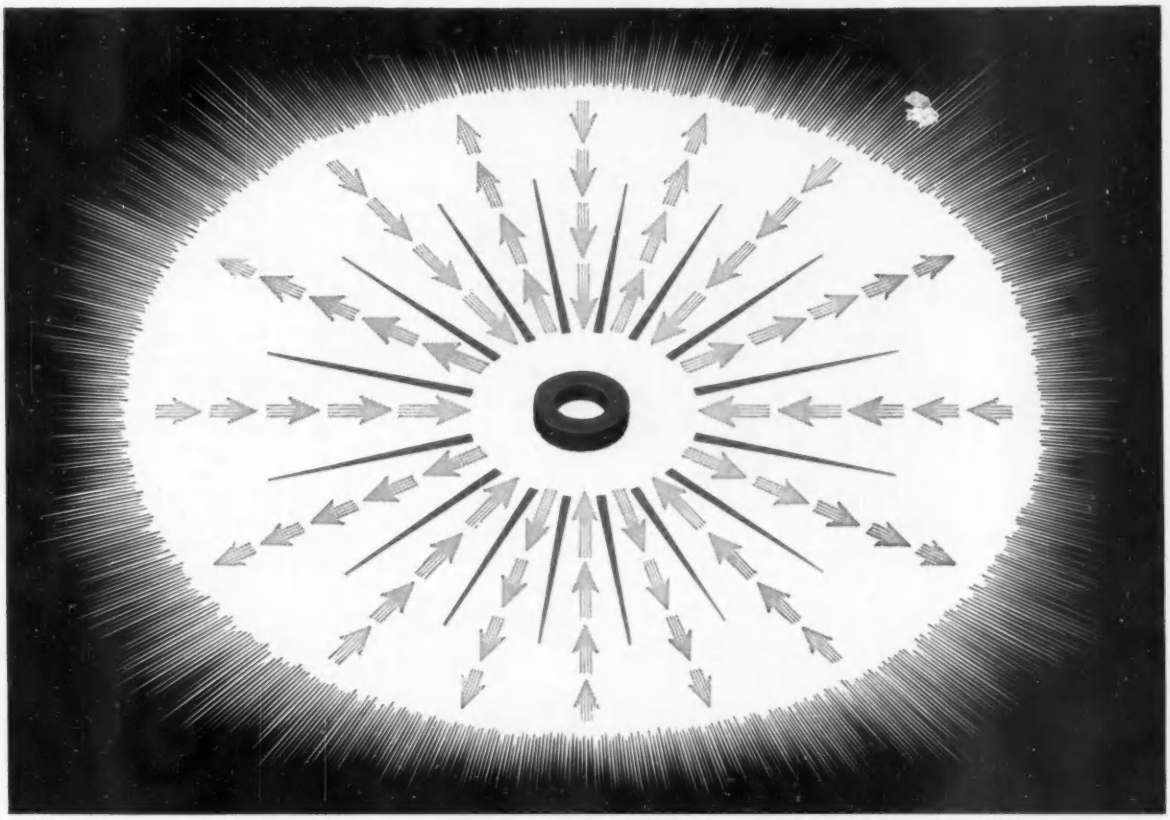
Packard Bell Computer Corp., an affiliate of Packard-Bell Electronics Corp.—in West Los Angeles. Under Max Palevsky, formerly with Bendix Aviation, who is vice-president and director, the new subsidiary will attempt to free advanced technology from the limitations imposed by current analog and digital techniques. Richard B. Leng, vice-president of the Technical Products Div. of the parent company, is president and chairman of the board.

Topp Mfg. Co., formerly a manufacturing division of Topp Industries, Inc.—in Los Angeles. Output will continue to be electronic, avionic, and automation devices, including airflow sensors, angle-of-attack computers, potentiometers, position transmitters, intervalometers, Mach computers, etc. Herbert J. Petersen, a founder of Topp Industries and its executive vice-president, is president.

J. J. Gano & Associates, a consulting firm specializing in power systems for electronic equipment — in Cambridge, Mass. In charge is Joseph J. Gano, formerly head of computer power-system development in MIT's Digital Computer and Lincoln laboratories. The service offered by his new company, Gano said, "bridges the field between the industrial power engineer and the electronic circuit designer".

Petro-Automation Industries, Ltd., under Duane A. Schmeekle, formerly with Shell Oil Co. of Edmonton, Alberta, Can.—in Edmonton. This company will do measurement and control work for the oil industry.

Transistorization of computers now a reality!



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Faster turnover . . . higher output . . . all of this with an .080" O.D. core which operates with driving currents in the range of 300-500 milliamperes!

The RCA 222M2 is comparable to high drive cores in its ability to withstand large disturbing current pulses without reversing its flux state.

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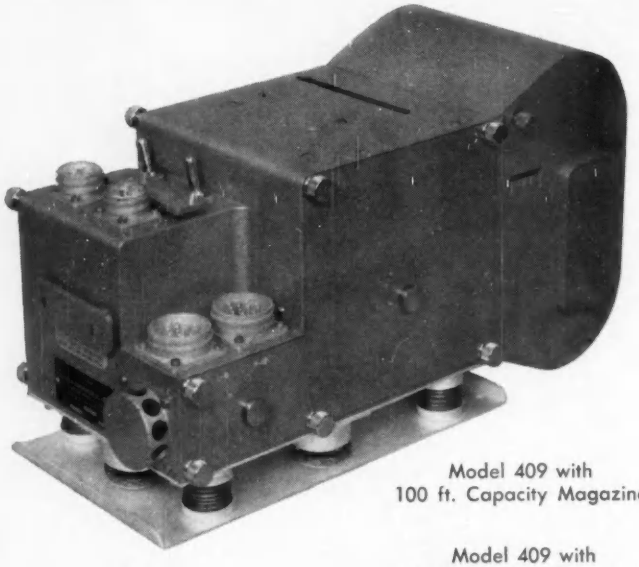
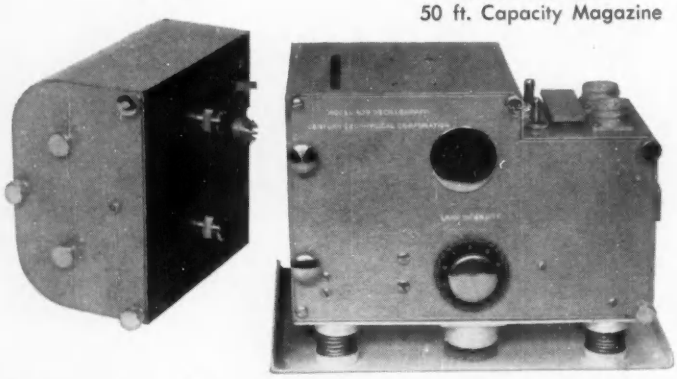
FOR VIBRATION, TEMPERATURE, STRESS, STRAIN RECORDING



Model 409 with
100 ft. Capacity Magazine

Model 409 with
50 ft. Capacity Magazine



The Century Model 409 Oscillograph was designed for operation under the most adverse conditions and more especially, where space and weight considerations are limited.

This Oscillograph is one of the smallest and most compact units available on the present market, yet it incorporates many features found in larger oscillographs, such as trace identification, trace viewing, continuously variable paper speeds and others. The Model 409 Oscillograph has been tested and proven to record faithfully during accelerations in excess of 20 g's. This makes it especially desirable for uses such as missile launching, parachute seat ejection, fighter aircraft and torpedo studies.

Write for Bulletin CGC-303 and CGC-301

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WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

John Barnes Keeps Newsmen Guessing About His Status

John L. Barnes, whose dream these days is to reach the moon (CtE, July, p. 19), has been finding it hard lately to reach some kind of accord with the directors of his own company. Toward the end of May, when Barnes was away from the Sherman Oaks, Calif. home of his Systems Laboratories Corp., the board of directors suddenly took action to oust him as president. No reason was anounced publicly, and CONTROL ENGINEERING, with its *Personality* sketch of Barnes all set up in type and ready to go, was only one of several publications affected. Among the others: "Aviation Age" and "American Scientist", both with advertisements scheduled showing Barnes as president of SLC.

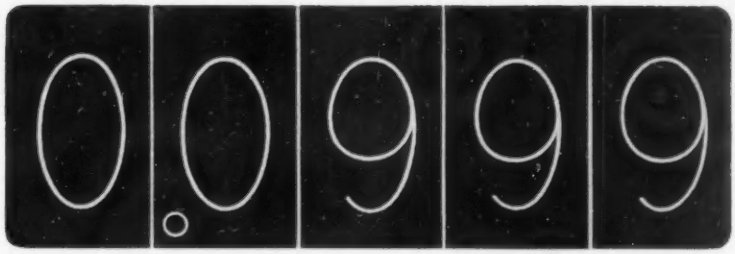
CtE's West Coast engineering editor, Mike Murphy, who had been doing his best with the short news rations released by SLC, reported, to the accompaniment of no small amount of headscratching, that it was true that Barnes was out as president but that he was still in as chairman of the board. Later, from PR man David Parry in Los Angeles came word that SLC had named a new slate of officers headed by James A. Marsh, president. And still later, another Parry release credited "Dr. James A. Marsh, SLC president", for a statement acknowledging receipt of an Air Force contract.

After weighing all factors, CtE ran Barnes's *Personality* just as it had been written shortly before the excitement started. It was just as well, too, for right up to the August deadline, the only thing that could be definitely determined about the goings-on at Sherman Oaks was that two factions had come into focus. One is made up of those board members who voted Barnes out, the other of those who are fighting for Barnes's reinstatement. This alone, however, indicates that Barnes is actively promoting his own return. It looks like a long affair, with some answers still to come.

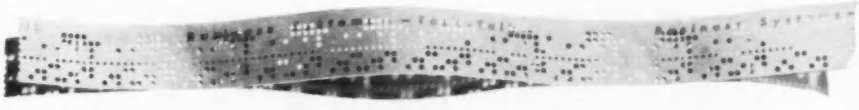
Barrett Elected by AIEE; ASME's Choice is Landis

Walter J. Barrett of the New Jersey Bell Telephone Co. is the new presi-

(Continued on page 158)



EITHER WAY OR BOTH



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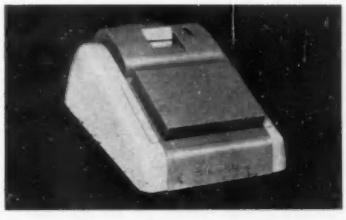
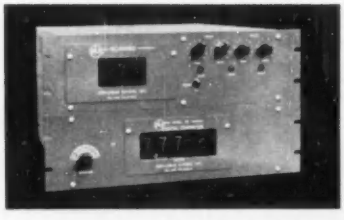


Clary Printers (both 8 column and 11 column) are supplied by NLS to be used in connection with DC digital voltmeters, 4 digit and 5 digit AC/DC voltmeters or ohmmeters.



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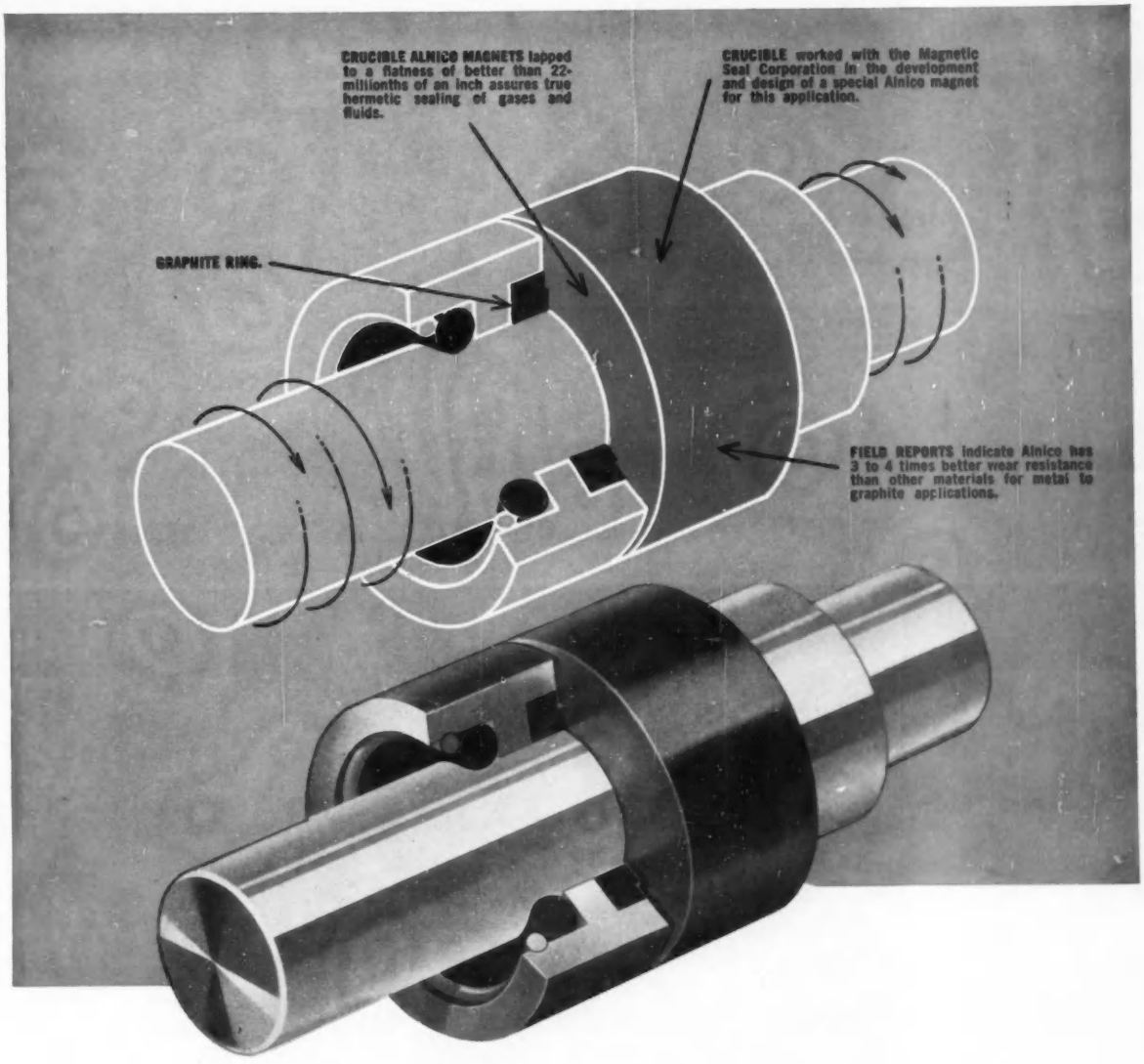
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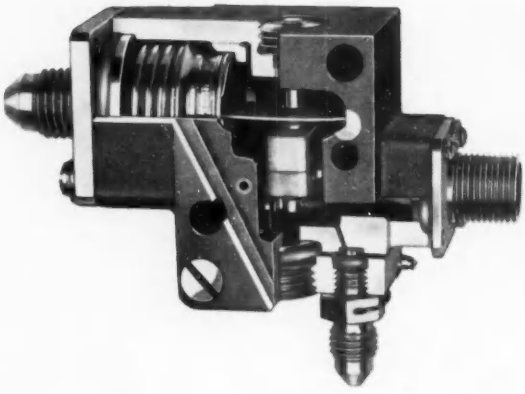

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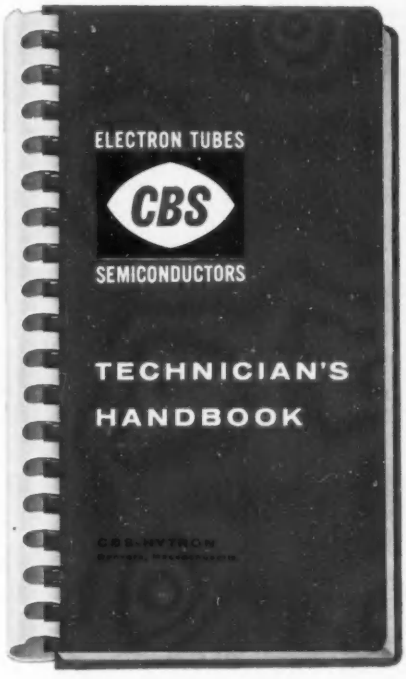

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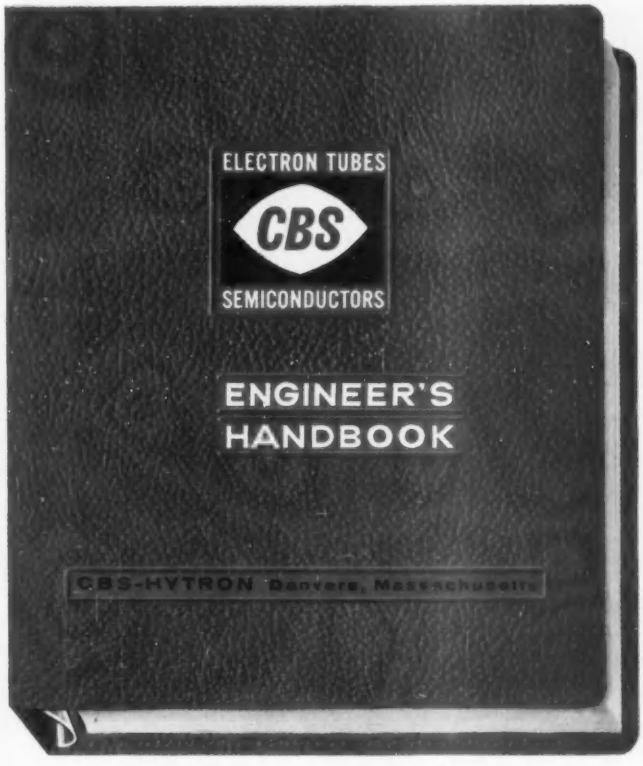

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- 450 pages
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- Complete RETMA engineering design data
- Seldom-used types tabulated for quick reference
- 300 two-color design curves
- 650 pages, two colors
- Handy 8¼ by 9⅜ inches
- 16-ring metal binder
- Appendix includes description of terms, symbols, characteristics ratings, etc.

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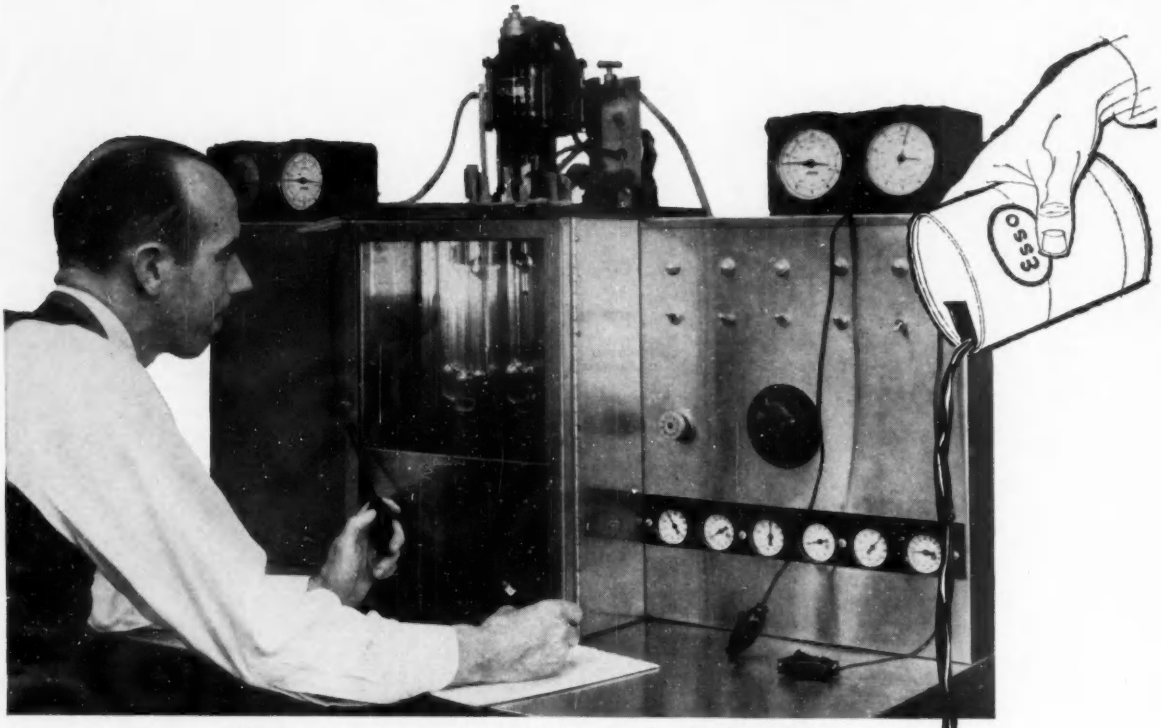

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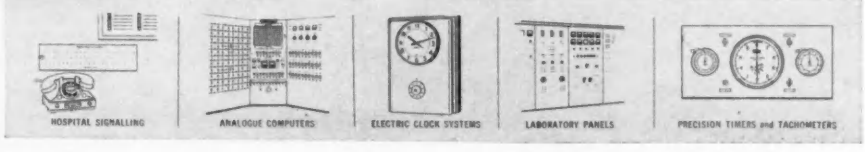

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HIGH SPEED SWITCHING TRANSISTOR

with response time in millimicrosecond range

GUARANTEED CHARACTERISTICS

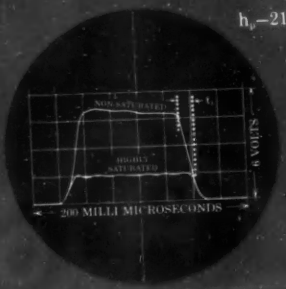
CHARACTERISTIC	CONDITION	VALUE
"ON"	$I_B = -.3ma$, $I_C = -2ma$. $I_B = -2.5ma$, $I_C = -8ma$.	$V_{CE} = -0.07V$. MAX. $V_{CE} = -0.10V$. MAX.
"OFF"	$V_{BE} = -0.10V$ $V_{CE} = -4.5V$	$I_C = -150\mu a$ MAX.
HOLE STORAGE FACTOR	$I_E = 1ma$, $I_B = -1ma$.	$K_s = 120m\mu$ sec MAX.*
h_{fe} (5mc Current Gain)	$V_C = -3V.$, $I_C = -.5ma.$, $f = 5mc.$	5 MIN.
C_{ob} (Common Base Output Capacity)	$V_C = -3V.$, $I_C = -.5ma.$	$6\mu\mu f$. MAX.
I_{CBO} (Collector Cutoff Current)	$V_{CB} = -5V.$	$3\mu a$ MAX.

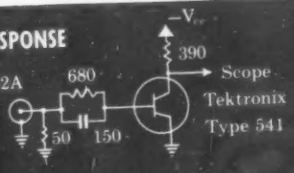
*K_s indicates total stored base charge per unit excess I_B.

MAXIMUM RATINGS

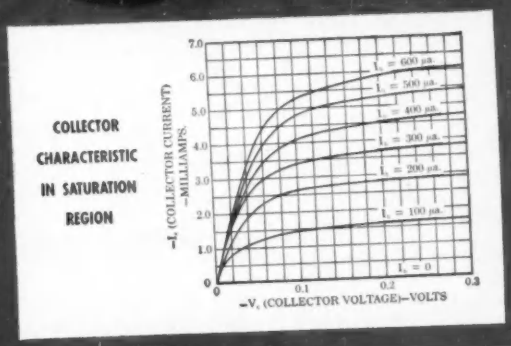
$V_{CE} = -6V.$ $I_C = -15ma.$ $P_C = 10mw$ @40°C.

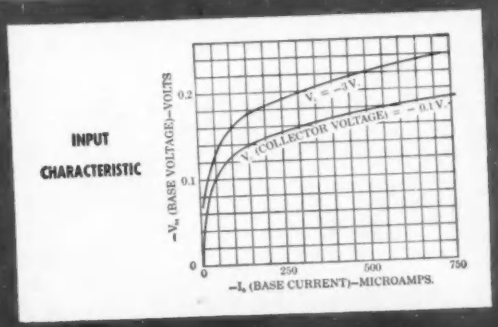
PULSE RESPONSE





Test Conditions: V_{cc} is set to −6V and pulse input is adjusted until transistor is just in saturation. V_{cc} is then lowered to −1.5V for saturated pulse curve. t_s = hole storage time.


COLLECTOR CHARACTERISTIC IN SATURATION REGION
$-I_c$ (COLLECTOR CURRENT) – MILLIAMPS.
$-V_c$ (COLLECTOR VOLTAGE)–VOLTS
I_b = 600 μa.
I_b = 500 μa.
I_b = 400 μa.
I_b = 300 μa.
I_b = 200 μa.
I_b = 100 μa.
I_b = 0



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CURE FOR CRAZY MISSILES

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SERVOSCOPE is the *only* servosystem analyzer that performs *all* of the checks necessary for guidance systems . . . an equivalent check-out with other means takes at least six separate instruments and assemblies. That's why you'll find the leading missile builders and suppliers using Servo Corporation's units in their plants.

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Maximum Leakage—5 c.c./min standard air
Ports—½ inch tube size
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Overall Dimensions—6.85 x 3.5 x 3.4 inches
Weight—1.87 lbs.

Endurance tested for 100,000 cycles. Integral bleed-down feature releases outlet pressure when inlet pressure is removed.

Weston Reducers feature close control of outlet pressure over a wide range of inlet pressures and outlet flows. Performance exceeds the requirements of specification MIL-R-8572A (Aer.). Designs are presently available with flow capacities up to 2000 SCFM! We invite your solicitation with reference to specific application.

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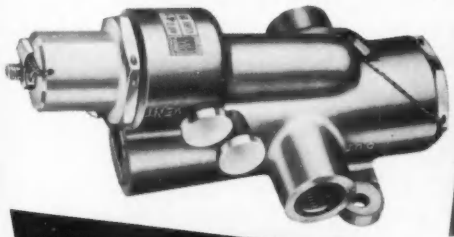

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CONTROL

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Bimetal, dial types. Dial sizes from 1″ to 5″—Stem lengths from 2½″ to 70″—Scale ranges from −150°F to +1000°F. Guaranteed accuracy to 1% of scale range. All stainless steel construction. Hermetically sealed dial. External dial reset device optional.

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Although we manufacture some 150 different instruments in more than 1,000 stock models, we have found that control system requirements are oftentimes too highly specialized to use any of them as is. As a result, our engineering department has become quite adept in coming up with the answer to suit the specification. Why not let us show you what we can do by way of specialized applications.

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RMC

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any MEASURES VARIABLE

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(micrometric or macrometric)
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DISPLAY RECORD CONTROL

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Utilizes the T-42 IONIZATION TRANSDUCER

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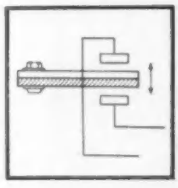
as high as 5 volts per $\mu\mu F \Delta c$, with a phase sensitive d-c output signal as high as ± 60 volts, yet stable enough to measure 0.01 volts.

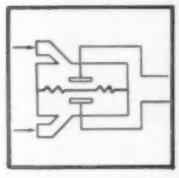
TO OPERATE

just provide a simple power supply and indicator . . . connect the desired capacitance configuration to the DECKER DELTA UNIT . . . and an analogous output signal is immediately available.

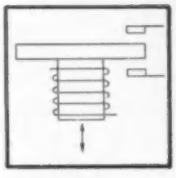
TEMPERATURE



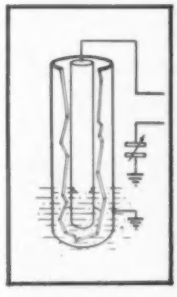
PRESSURE



VIBRATION



LIQUID LEVEL



Detailed information on the DECKER DELTA UNIT—priced at $115.00, complete with probe and cable—is in Instrument Data Sheet 901-1, available upon request to Technical Literature Section.

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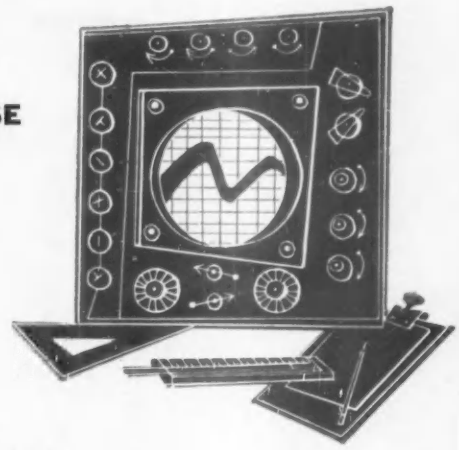


Aircraft Companies Study Plunge Into Industrial Control Markets

Aircraft companies are quietly reconnoitering the industrial control market for possible invasion. At the same time some traditionally exclusive suppliers to the aircraft industry and military are responding to rumors that their aircraft business may dry up by readying marketing plans for plunges into such widely divergent fields as chemical processing controls, numerical machine tool control, computers, and control components.

Diversification

Diversification attempts by the aircraft industry are not new. Plane makers have been looking for new fields, off and on, since the drastic cutbacks of 1946 (when Douglas Aircraft Co., for example, laid off 90,000 workers in one week). Most of the excursions into new fields ended up unprofitably and the plane makers hurried back to building aircraft.

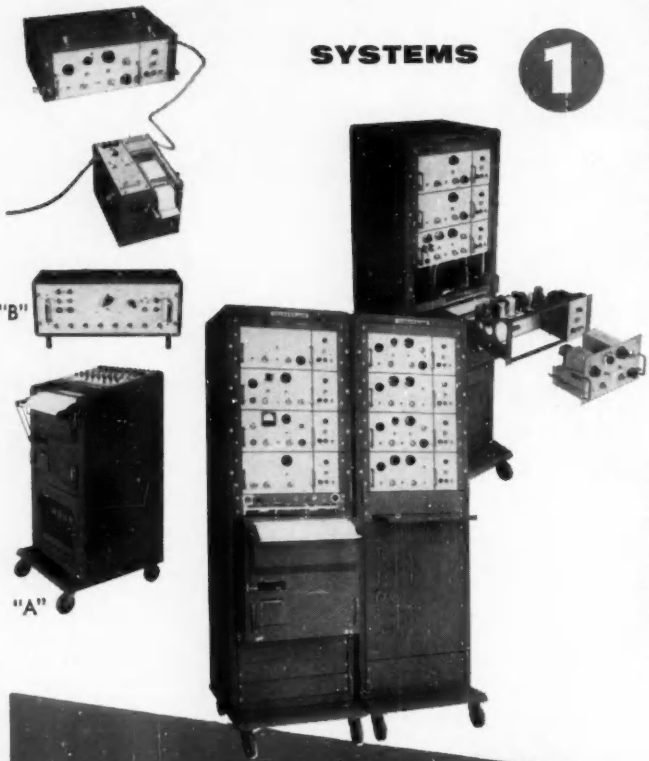
But there's sound logic behind an aircraft invasion of control fields now. Three recent developments have forced the plane builders into advanced control studies: 1) the automatic supersonic airplane, which is really a platform for complex control systems; 2) the big numerical control machine tool program generated by the USAF; and 3) the accelerated guided missile program.

Pressure's on

Recently, new pressure has been felt: U.S. military strategists are switching from manned aircraft to unmanned missiles. That means the Air Force is narrowing its buying to a smaller number of weapons systems and will need fewer prime contractors. Gen. David H. Baker, chief of procurement and production for USAF's Air Material Command, warns that the aircraft industry may have as much as 50 million sq ft of idle floor space in 1960. That's incentive enough to start anybody looking for new markets. Here's what's happening:

autonetics—computers and numerical control

North American Aviation set up its Autonetics Div. several years ago to design, develop, and manufacture control components and systems for the military and the aircraft industry. The company has developed digital differential analyzers, general-purpose computers, and other devices for the Air Force. But now NAA is looking beyond the aircraft industry. Its



SYSTEMS 1

BASIC "150" assemblies housed in either vertical mobile cabinets or separate portable cases are available in 1-, 2-, 4-, 6- and 8-channel models. Each is equipped with driver amplifiers of current feedback design and regulated power supplies for *each* channel, and a recorder featuring *nine* extremely accurate paper speeds on 2- to 8-channel models, five on single channel units. Appropriate plug-in preamplifiers quickly and efficiently equip a basic assembly for recording virtually any 0-100 cps phenomena.

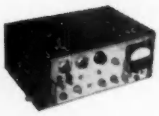
new 6- and 8-channel analog readout systems

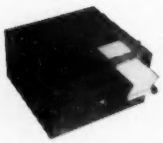
In addition, complete Sanborn systems from 2- to 8-channels are available for recording analog computer outputs. These are equipped with dual-channel DC amplifiers, for single-ended or push-pull signals — input impedance 5 megohms each input lead to ground — drift less than 0.5 mm/hr. — frequency response down 2 db at 60 cycles for all amplitudes to 4 cm peak to peak. Newest of the computer readout recorders are the 6- and 8-channel console systems (8-channel illustrated — "A" at left). The Model 183 Programmer in a Model 184 case ("B" at left) is optional for use with the 6- and 8-channel consoles. The Programmer automatically turns on chart drive, feeds calibrated signals to all channels, reads computer DC levels, determines the length of record, and shuts off the paper drive.

SANBORN

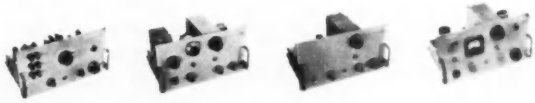
oscillographic recording equipment

3 UNIT INSTRUMENTS





All Sanborn Preamplifiers and Recorders, as well as various other units, are available separately for specialized applications or use as "original equipment" in other apparatus. Instruments include the Model 150-300/700 Wide Band Driver Amplifier and Power Supply, for use with low power galvanometer elements, a 'scope and/or panel meter. When equipped with suitable "150" preamplifier, this amplifier provides a portable indicator for strain, force, pressure, temperature, AC watts, audio level, etc. Other units include the Model 150-1900 Master Oscillator Power Amplifier; Model 150-3100 Triplexer; Model 601 and 602 galvanometers; Model 150-2900 Dual-Channel DC Amplifier.



2 PREAMPLIFIERS

A choice of *twelve* "150 Series" plug-in preamplifiers is now available, to equip systems for any of numerous recording problems. Improved control of input signals results from attenuator ratios of 1, 2, 5, etc., and calibrated zero suppression on AC-DC, Carrier, and Low Level DC Coupling, Frequency Meter, and Chopper Stabilized DC models. Other "150" preamplifiers include: Servo Monitor, Log-Audio, AC Wattmeter, RMS Volt/Ammeter, 400 cycle Frequency Deviation, and Triplexer.

Added to these three aspects of Sanborn Oscillographic Recording Equipment are the basic advantages of inkless recording in true rectangular coordinates, to provide accurate, easily interpreted records; high torque galvanometer (10 ma develops 200,000 dyne cm.); one percent linearity resulting from current feedback driver amplifiers and high torque galvanometers (maximum error is ¼ mm in middle 4 cm of chart, ½ mm across entire chart); controls for timing, manual and remote coding.

Take advantage of the scope and flexibility of Sanborn equipment to answer your recording requirements. Sanborn engineers will be glad to provide further information and application assistance whenever you wish. Contact your local representative or write to the main office below.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 WYMAN ST. WALTHAM 54, MASS.

RECOMP (a general-purpose, all-transistor, digital computer), says NAA, can be used for everything from mathematical computation to process control. In addition, Autonetics has designed and built NUMIL, a two-dimensional numerical control for a profiler. The division is also developing a three-axis general-purpose numerical control that will fit on a variety of machine tools.

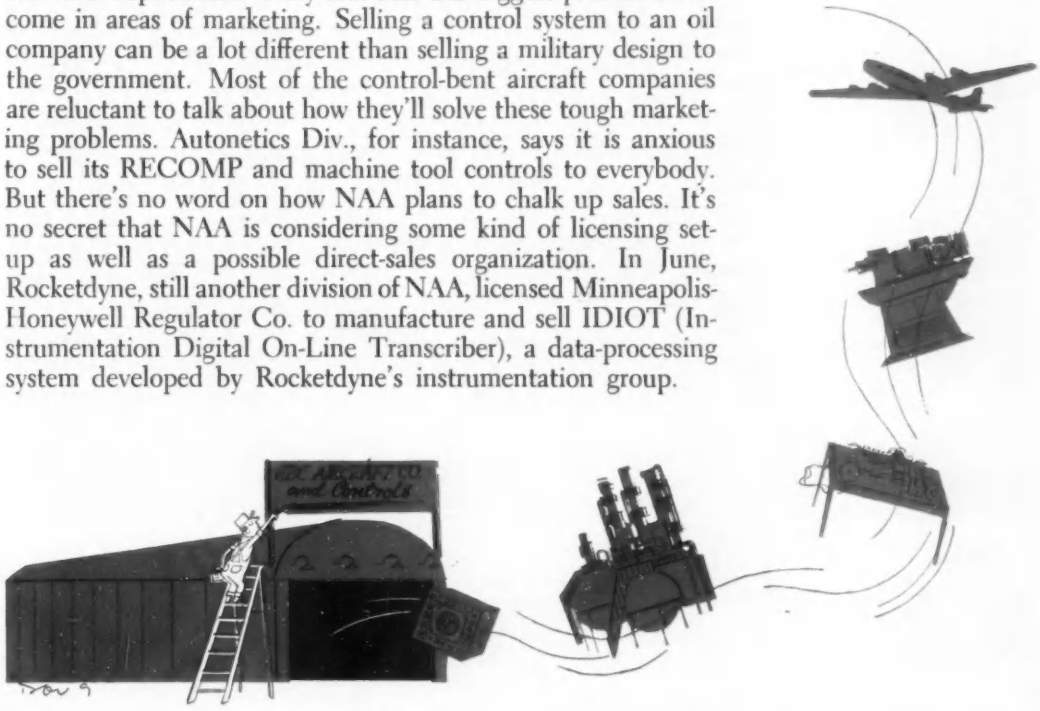
Lockheed—interest

Lockheed's Missile Div. makes no bones about its interest in the industrial control field. Right now the division is totally occupied fulfilling defense commitments, but it has capabilities in other areas which it hopes to use later. Lockheed had a taste of control work and liked it. When the California Div. (which builds both commercial and military aircraft) bought a numerically controlled machine tool and ran into trouble getting the control to work, it called on the company's Missile Div. for help. The missile engineers came up with a new digital control that worked better than the original equipment.

Hughes—computer for process control?

Hughes Aircraft Co. has also set its sights on industrial markets. Traditionally a supplier to the military, Hughes has previously made several false starts after industrial control business. But this one, say company spokesmen, is serious. Hughes Products has already been set up as a separate division to concentrate on commercial markets. One area of prime interest: use of computers in industrial processes and process controls.

There's no doubt that the aircraft companies are strong on technical capabilities. They feel that the biggest problems will come in areas of marketing. Selling a control system to an oil company can be a lot different than selling a military design to the government. Most of the control-bent aircraft companies are reluctant to talk about how they'll solve these tough marketing problems. Autonetics Div., for instance, says it is anxious to sell its RECOMP and machine tool controls to everybody. But there's no word on how NAA plans to chalk up sales. It's no secret that NAA is considering some kind of licensing setup as well as a possible direct-sales organization. In June, Rocketdyne, still another division of NAA, licensed Minneapolis-Honeywell Regulator Co. to manufacture and sell IDIOT (Instrumentation Digital On-Line Transcriber), a data-processing system developed by Rocketdyne's instrumentation group.

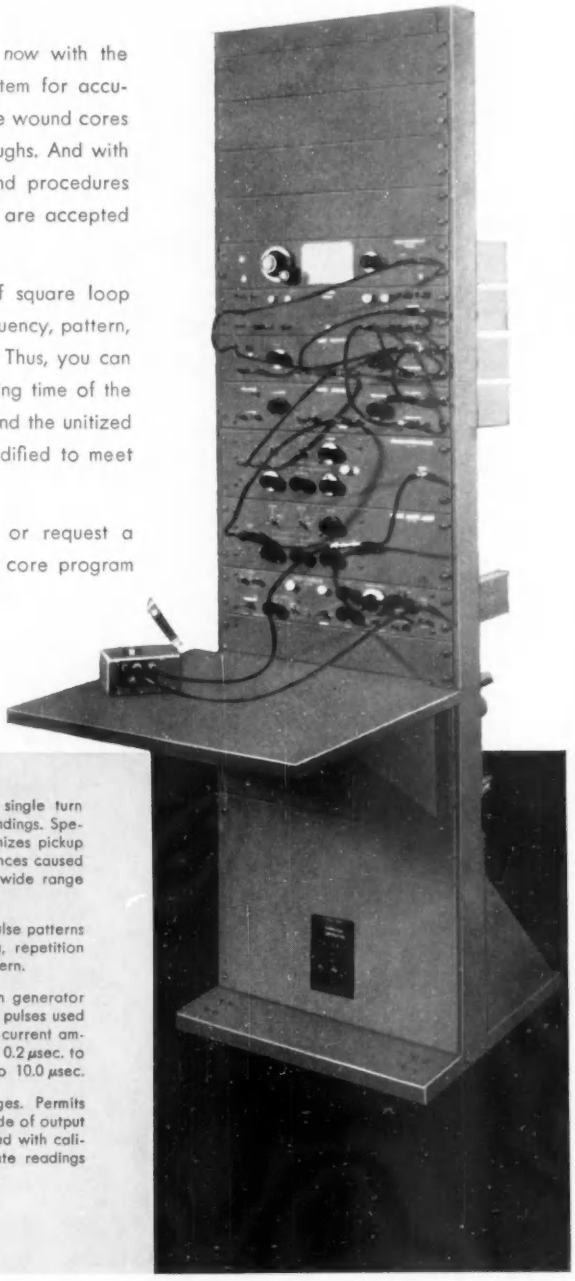


HOW TO TEST CORES

You can get your core program off the ground *now* with the Burroughs BCT-301. This complete and flexible system for accurately measuring the operating characteristics of tape wound cores is the result of six years of core research at Burroughs. And with it, you get the benefit of advanced techniques and procedures which are now in everyday use at Burroughs, and are accepted practice among major core manufacturers.

Designed expressly for the individual testing of square loop cores, the BCT-301 allows precise control over frequency, pattern, amplitude, and rise time of the core driving signal. Thus, you can get extremely accurate measurements of the switching time of the core as well as the amplitude of the output pulse. And the unitized sections of the BCT-301 can be expanded and modified to meet new testing requirements as they arise.

Write for additional details on the BCT-301, or request a demonstration of how this new tool can get your core program off the ground *now*.



specifications

tools for engineers

core mounting jig: Low-noise test mounting jig applies tight single turn loops around core for input and output windings. Special electrical and mechanical design minimizes pickup by the secondary as well as other disturbances caused by air flux. Adjustable pins accommodate wide range of bobbin sizes with equal precision.

pattern generator: Provides extreme flexibility in generating pulse patterns applied to core, controlling pulse spacing, repetition rate of cycle, and number of pulses in pattern.

current drivers: Two drivers convert voltages from pattern generator into positive and negative constant current pulses used for driving core. Front panel controls vary current amplitude from 0 to 1.0 ampere; rise time from 0.2 μsec. to 1.0 μsec.; pulse duration from 1.0 μsec. to 10.0 μsec.

calibrator: Accurately measures currents and voltages. Permits measurement of driving current and amplitude of output voltage with an error of less than 1%. Used with calibrated oscilloscope, permits highly accurate readings of switching time.

power supply: Provides seven regulated d-c voltages.

Burroughs Corporation • ELECTRONIC INSTRUMENTS DIVISION, DEPT. A, 1209 VINE STREET, PHILADELPHIA 7, PA.

Control ENGINEERING
AUGUST 1957

Application Engineering Costs Money

Recently one of us moderated a discussion on how much "free" application engineering should go with the purchase of measurement and control products. Three users, representing an aircraft-engine manufacturer, a chemical processing company, and a process-equipment contractor, were lined up against three men employed by manufacturers of analytical instruments, control system components, and complete control systems. The question—should there be a base price for each component and an added fee for the engineering required to fit it into an installation? – started a lively discussion. But there was no impassioned debate, and both the "pros" and the "cons" agreed on these points after a short argument:

▶ "Free" application engineering does not exist. No manufacturer can give away an expensive service; it must go into the average price of the product and can have only one effect on prices – to raise them.

▶ Control engineers working for the larger users have become quite competent at evaluating and applying system components – so competent that to sell to them the manufacturer has had to upgrade the technical know-how of his sales staff.

▶ Complete application literature, which the control engineer in the small as well as large outfit can use to educate himself, must accompany catalogs listing available equipment. (CtE readers, who represent a cross-section of control engineers, submit four times as many inquiries for product application literature as for bulletins announcing and listing the products themselves.)

A couple of useful generalizations resulted when we correlated this discussion with others we have had on application engineering. First, the upper level of prices for products sold in this field is influenced by one prime question – does the manufacturer sell performance or hardware? The degree to which he sells performance determines the degree to which he furnishes application engineering, and since application engineering is a value added on top of design and manufacturing costs, it must affect the level of prices. Second, education of both the user and the manufacturer in the best-known techniques of application engineering is our best guarantee of top system performance.

THE EDITORS

new -*hp*- 560A

DIGITAL RECORDER

Continuous digital record for your frequency counter!

Prints 11-digit information at 5 lines per second

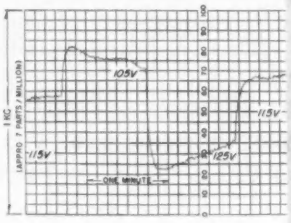
Controlled by electronic or mechanical devices

Direct print-out from all -*hp*- counters

Analog output for strip-chart recorder

Expanded scale; full scale can represent $1/10^7$

Frequency stability vs. line voltage; 150 MC oscillator



SPECIFICATIONS

Accuracy: Identical to that of basic counter used.
Printing Rate: Controlled by counter, 5 lines/sec. max.
Digit Capacity: 11 digits per line.
Driving Source: Parallel entry staircase voltages derived from standard digital frequency counters such as Hewlett-Packard types. Staircase descends from +135 v to +55 v as the count progresses from 0 to 9. Internal impedance of staircase source should be approximately 700,000 ohms.
Print Command Signal: 1 μsec or greater, positive or negative pulse, 15 volts p-p or greater.
Paper Required: Standard 3" roll or folded paper.
Line Spacing: Single or double, adjustable.
Analog Signal: Any three consecutive digits may be selected by selector switch. Output is function of selected digits. For example, if consecutive digits were 3, 8, and 6, output voltage would be 38.6 millivolts or 0.386 ma.
Output Available: 1 milliamp for galvanometer strip-chart recorders. 100 millivolts for potentiometer strip-chart recorders.
Power: 105/125 volts, 60 cycles, 250 watts.
Dimensions: Cabinet Mount: 20½" wide, 12½" high, 18½" deep. (Rack Mount available).
Weight: Net 60 lbs. Shipping 100 lbs.
Accessories Available: 1052-24, 3" folded paper, 48/carton.
Price: Price on request.

Data subject to change without notice

Model 560A is a new kind of continuous duty instrument designed from the chassis up for digital recording of frequency counter output and similar information. It is specifically useful in recording time functions, telemetered data, information to be monitored, tabulated and plotted and system drift phenomena. It is also a convenient digital/analog converter for strip-chart production.

Frequency counter accuracy

Since -*hp*- 560A is a slave to its information source, accuracy is that of the counter or other source. The instrument's motor-driven print mechanism comprises 11 number wheels and associated mixing-comparator circuits. The print mechanism is controlled by a staircase voltage and external print command pulse. The availability of 11-digit lines means secondary or coding data may be printed on the same line as primary data.

Complete details from your -*hp*- representative, or write direct.

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Servo Modulators — I

where and why they're used, characteristics of the basic types

THE GIST: Modulation plays a fundamental role in closed-loop systems because it carries the intelligence by which a system is controlled. Improper modulator choice can severely affect overall system performance.

This group of articles covers the application of suppressed-carrier modulators in control systems. It is thus aimed at only one small area of modulation in electrical engineering. In communications, the transmission of any sort of intelligence would hardly be possible without some type of modulation. Television, radio, telephony, facsimile, frequency shifting and multiplication, noise reduction, radar, etc., all rely on modulation.

The first article tells how modulators work, discusses the six broad classes of control system applications, and tabulates the important performance specifications of the various types of servo modulators. Succeeding articles will cover specific modulators within each type, list commercially available units, and show detailed circuitry and test-obtained characteristic curves of several special modulators.

BASIL T. BARBER, Sperry Gyroscope Co.

A servo modulator converts a polarity-sensitive dc voltage to a phase-sensitive ac voltage. The output must indicate the sense as well as the magnitude of the input signal. A change of sense is indicated by inverting the output voltage waveform; opposite polarity dc input signals yield ac outputs that are 180 deg out of phase. When there is no input signal, the ac output voltage should be close to zero.

Depending on the parameter varied, the modulation can be made to control the amplitude, phase, or frequency of a signal. Since most ac servomechanisms are of the continuous carrier type, however, the choice is restricted to suppressed-carrier amplitude modulation, where the information function (input) is multiplied by a sinusoidal carrier function (reference). Thus the modulator must be capable of accurately multiplying two variables, an inherently difficult process. And to convey any information, the output must occupy a nonzero band of frequencies.

Let the input signal to the modulator be represented by $A \cos \omega_M t$, where A is the amplitude and ω_M is the modulated frequency. The carrier can be represented by $\cos \omega_C t$, where ω_C is the modulating frequency. Then for 100 percent modulation, the output of a suppressed-carrier amplitude modulator is

$$E_O = \frac{A}{2} [K_1 \cos (\omega_C - \omega_M) t + K_2 \cos (\omega_C + \omega_M) t] + K_3 \cos \omega_C t + K_4 \cos n\omega_C t$$

The various K factors determine modulator performance. Factors K_1 and K_2 determine a modulator's conversion ratio (gain), linearity, symmetry, frequency response, and overall balance, while K_3 denotes its null and dynamic range and K_4 the amount of harmonic content present at the output. In an ideal modulator, $K_1 = K_2$ and $K_3 = K_4 = 0$.

Modulator types

Modulators work by modifying the conductance or impedance of some element of the modulator as a function of time. Time, in turn, is controlled either by a voltage or current representative of the carrier or by the geometry of a mechanically variable element. Depending on the nature of the modification and the mode of controlling time, modulators can be classified as follows:

ELECTROMECHANICAL MODULATORS—Choppers, variable-reactance, induction or galvanometer.

ELECTRONIC MODULATORS—MULTIGRID VACUUM TUBES: electrode, cutoff, variable-gain, gates or beam-detection tubes. VACUUM DIODES.

SOLID-STATE MODULATORS—Semiconductor diodes, transistors, voltage-sensitive capacitors, nonlinear resistors, thermistors, photoconductive elements.

MAGNETIC MODULATORS—Magnetometers, saturable reactors, double- and single-frequency units, bismuth alloys.

The performance characteristics of the major types of modulators (electromechanical, electronic, semiconductor, magnetic, and photoconductive) are listed in the four-page table at the end of this article. Detailed circuit configurations of the various subtypes and information on commercially available units are included in future articles of this group.

Modulator applications

Numerous applications require modulators. The most general application categories are as follows:

Dc transducers—There are many transducers that yield a dc output: thermocouples, strain gages, thermopiles, and certain pressure transducers are in this category. The dc types are characterized by high accuracy, sensitivity, and resolution; the absence of quadrature; and very low noise levels. When used in control systems, transducer output must be amplified. Ac amplification is preferable because design is simple, maintenance is low, and there are no drift or balance problems. In addition, in low-powered systems ac servomotors are inherently faster and have no rectifiers and brushes.

Stabilization and dynamic compensation—In ac servo systems it is usually necessary to modify the dynamic response of the servo amplifier. This can be done by altering the carrier response by modifying the external load on the system, or, more effectively and simply, by separating the signal intelligence from the carrier signal with a demodulator, altering its frequency characteristics with a simple *RC* network, and then remodulating to convert the signal back to ac. Here the compensation can be performed in either the primary or secondary feedback loops of the system, and practically any type of dynamic compensation can be realized. This method may be cheaper than using damping generators or inertially damped servomotors, and offers wider flexibility to the designer. Ac compensating networks are usually unsatisfactory unless frequency is precisely regulated. In addition, nonlinear compensation is simpler if the signal is dc.

High-gain ac amplifiers—In very high-gain servo amplifiers, quadrature is a limiting factor, because it usually drives the amplifier into saturation and reduces amplifier usefulness. Demodulation-modulation is a practical solution in this case; gains as high as 1,000,000 have been realized using the demodulation-modulation technique.

Carrier frequency conversion and telemetering—Control signals, propagated or received by radio or radar, are usually translated by modulators into lower carrier frequencies before being applied to electromechanical components.

Bandwidth limiting—The effective separation of noise and intelligence is considerably important in control systems for guided missiles, radar, and sonar devices. One technique widely used for this separation is bandwidth limiting (variable, nonlinear, or a function of a controlling or controlled parameter), usually performed at a dc level followed by a modulator. This is because designing very narrow filters for dc signals is considerably less formidable than designing corresponding ac or mechanical filters. Bandwidth control is also used in special analog computers for autocorrelation studies.

Other modulator uses—Since modulator operation is based on the concept of multiplication, it can also be extended to integration. It is then possible to design computers without any moving parts that will rival their digital counterparts. Airborne computers using these techniques are in operation. Modulators have also found extensive use in high-gain dc amplifiers, and in the stabilization loops for these amplifiers. Low drift and wide bandwidth can be obtained by using modulators in the feedback loops.

Figures 1 through 5 show typical modulator applications and briefly describe important characteristics for modulators located at various points in control systems. The references included with this article are of a general nature and pertain to the whole subject of modulation. Succeeding articles will contain specific references, grouped by type of modulator.

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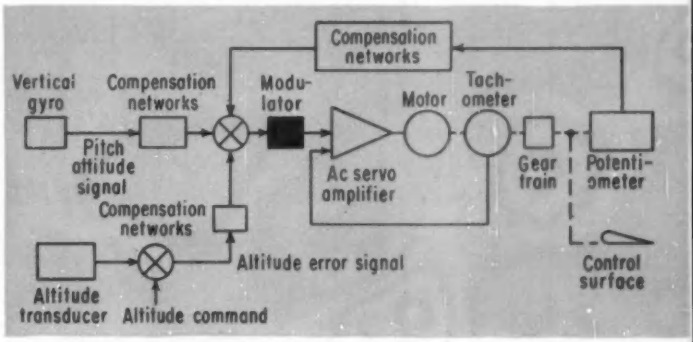
Tables follow on pages 68-71

FIG. 1 Many transducers used in aircraft applications are dc-operated because the basic aircraft power supply is dc. When used with ac servomechanisms in automatic flight control systems, transducer dc output must be converted to ac by modulation. Since the servo shown here is of the null-seeking type, null-level and drift are the only two characteristics of the modulator that are critical (since it is in the forward loop of the system, certain of its nonideal characteristics are compensated for by the feedback around the complete loop). Simple vacuum-tube or semiconductor-diode modulators are satisfactory.



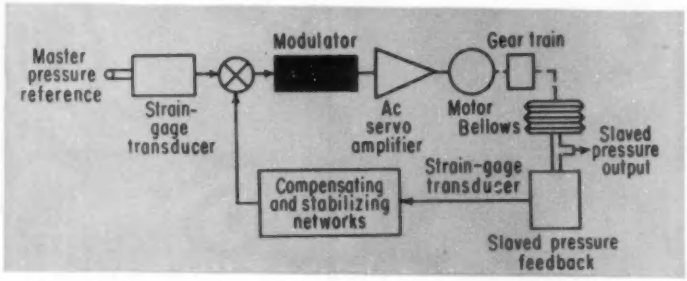
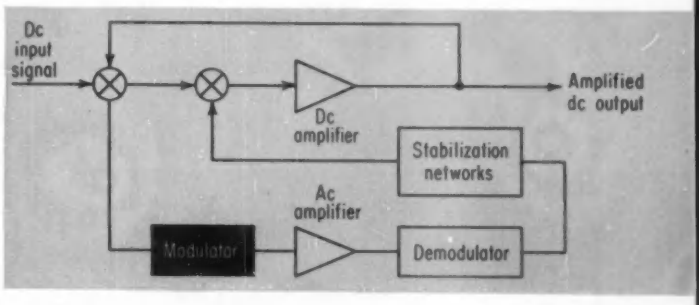


FIG. 2. In the type of strain-gage application shown here, a dc reference is often used to eliminate quadrature and prevent harmonic saturation. The high precision and sensitivity required calls for electromechanical chopper modulators.

FIG. 3. This shows a somewhat different application. Dc-amplifier drift can be reduced by amplifying the actual drift error and feeding it back negatively to the main dc amplifier. Since the modulator is in a secondary feedback loop, its performance characteristics are not critical. Triode vacuum-tube modulators are often used here.



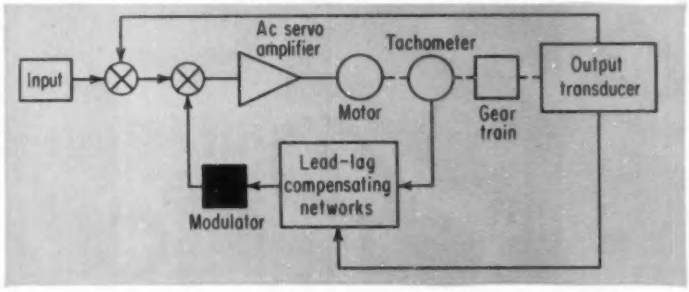
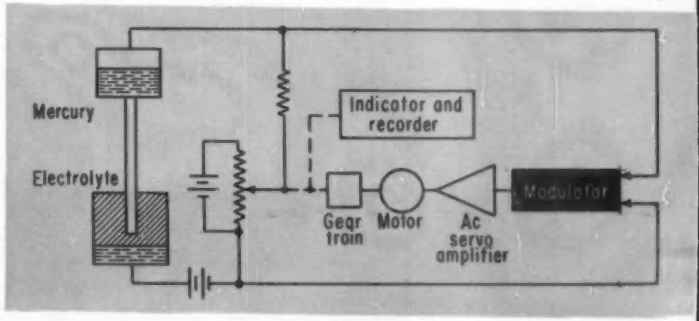


FIG. 4. This shows a technique for compensating or stabilizing a servo system by means of a secondary feedback loop. Practically any type of response can be attained by this method, and it is usually cheaper and more flexible than other techniques. Although it depends on the servo amplifier, magnetic modulators are often used here.

FIG. 5. Precise measurements of chemical, photoelectric, or thermal reactions use dc reference voltages almost exclusively to eliminate the effect of alternating currents on the transducer or chemical compounds and to reduce quadrature and noise. The minute currents involved require modulators and servo amplifiers with very high input impedances and gain. Electronic amplifiers and mechanical modulators have proved to be best—voltage gains as high as 10,000,000 are attainable. In this electrochemograph the output current of the mercury-electrolyte combination is a measure of the number of ions and the polarizing voltage identifies the substance. Currents as low as 10^{-7} amps can be measured and recorded[15].



MODULATOR TYPES AND THEIR PERFORMANCE CHARACTERISTICS

	IMPORTANT PERFORMANCE SPECIFICATIONS	GENERAL REMARKS	TYPES OF MODULATORS						
			Electromechanical (Choppers)	Electronic		Semiconductors		Magnetic	Photo-conductive cells
				Multielement tubes	Vacuum diodes	Diodes	Transistors		
INPUT CHARACTERISTICS	INPUT IMPEDANCE	Input impedance should be as high as possible to prevent adverse loading effects on transducer or previous stage. Depending on particular transducer used, some degree of input impedance matching may be required for best linearity or maximum gain. In addition, adequate impedance separation should be available if dc compensation methods are used. Impedance should preferably be resistive to avoid tuning effects (resonance) and the associated phase shift and frequency-response limitation. Impedance should also be constant and independent of input level.	Independent parameter; determined by output load and required null.	Depends on element used; very high when input is to grid.	Usually below 10,000 ohms.	Below 10,000 ohms. A function of voltage level. Should be as low as possible to minimize effects of temperature variation.	Critical parameter; usually below 10,000 ohms.	500 to 3,000 ohms; better at low impedance level.	High, 200,000 to 300,000 ohms; up to 1 megohm possible.
	PERCENT OF CARRIER PRESENT AT INPUT	Adequate isolation is required between modulating carrier and dc input, since any interaction will adversely affect transducer accuracy, limit dynamic range, and result in a type of intermodulation distortion that cannot be reduced by filtering.	Complete carrier absence.	Some leakage present.	About 1 percent.	Less than 1 percent. High isolation possible depending on element back resistance. Complete isolation impossible.		1 to 2 percent depending on core matching. A function of temperature.	Approximately 5 percent.
	MAXIMUM ALLOWABLE INPUT	Since large transients can be expected in most servos before system settles out, modulator should be able to accept considerably overrated input level. An excessive input may drive the modulator into permanent saturation, cause "memory" effects resulting in time delays, distort its linearity, increase its null, or even burn it out.	Limited by contact rating. Typical values are from 3 to 10 volts at 10 to 1 milliamp. Higher voltages with lower currents possible. Maximum 100 volts at 2 milliamp on intermittent duty cycle.	Restricted range for good linearity. Up to a few volts.	Not critical; depends on breakdown voltage of element.	Function of breakdown voltage of diode or transistor and of reference voltage. Usually below 1 volt.		Limited to about 250 millivolts. Overload should not exceed a few volts. Some "memory" effects.	Up to 40 volts with no adverse effects. Normal input below 1 volt.
	INPUT FORM	Either single-ended or push-pull. Most modulators accept single-ended inputs. Push-pull input facilitates modulator design, but its generation is somewhat more difficult and long term balance becomes critical. Some modulators will accept two inputs and modulate their difference without summing networks, thus performing the comparator function. Input should be almost pure dc. If ac components are present they will be reflected at the modulator output as sums and differences of the modulated and modulating frequencies.	Single-ended or push-pull.	Single-ended or push-pull.	Single-ended or push-pull.	Single-ended in most transistor modulators. Diode units can accommodate push-pull circuits or act as error-sensitive devices.		Single-ended or push-pull.	Single-ended or push-pull.
OUTPUT CHARACTERISTICS	OUTPUT IMPEDANCE	Preferably resistive to avoid resonance problems. Value depends on type of amplifier fed by the modulator. With transistor or magnetic amplifiers, a low impedance is used to reduce insertion loss. The performance of some semiconductor modulators is affected by output impedance. In addition, output impedance should not be a function of output voltage, and it should have equal values for both input polarities to prevent nonlinear effects.	Same as input. Independent parameter and a function of input source impedance.	Same as tube plate impedance. Usually from 10,000 to 50,000 ohms.	Depends on type of modulator; usually low.	High and low impedance levels available.	Critical parameter; usually between 1,000 and 10,000 ohms.	4,000 to 15,000 ohms.	Function of input impedance and nominal resistance of lead-sulfide element. Usually about 150,000 ohms.
	OPERATING LEVEL	Output is usually restricted to a few volts within the linear region of modulator. High-level units also have high nulls and balancing problem is more critical.	Same as input.	Up to 50 volts possible. Usually a few volts for good linearity.	Low, about 1 to 2 volts if low null desirable; higher levels possible.	Mostly low-level units for good linearity, but not suited for very low inputs.	Basically a low-level device; 1 to 2 volts maximum.	Low-level device.	Low level; below about 1 volt.
	DRIFT	Modulator zero drift is defined as rate of change of its null with time. Usually given on an equivalent input value of microvolts or microwatts, since it is a function of inherent amplifier gain. Temperature, and variations in carrier frequency and voltage are main factors. With high-gain amplifiers drift can cause considerable unbalance.	Practically no drift. A few tenths of millivolt over 8 hours.	Function of temperature, heater-voltage variation, and age. As much as 25 microvolts per min.	Function of heater-voltage variation. Usually about 1 microvolt per min.	As low as 1 microvolt per min over 8-hour periods. Affected by temperature.	Order of magnitude better than diodes.	0.2 percent; affected by bias.	1 to 5 microvolts per min; function of temperature.

OUTPUT CHARACTERISTICS

MAXIMUM OUTPUT	Maximum output together with modulator null determines dynamic range and resolution. Saturation should be symmetrical to eliminate "memory" and nonlinear effects on succeeding stages.	Limited by maximum input specifications. Load should be resistive to prevent large transients across contacts.	Wide flexibility as to load matching.	Load can be critical; 25 to 50 volts possible into high impedance.	Up to 10 volts within linear region. Up to 50 volts reported.	1 to 2 volts.	10 volts into a high-impedance load.	Vicinity of 1 volt.
NULL	Null is defined as residual noise output with input grounded. It consists of a number of voltages in phase and in quadrature with carrier, and some even or odd harmonics. Although null signal in phase (or quadrature) with carrier is most important, the other extraneous signals are also influential as they affect saturation of succeeding amplifier. Modulator null value determines its dynamic range and limits maximum gain possible in succeeding amplifier before saturation. Usually given as equivalent noise level referred to input to take into account modulator gain. Null is affected by degree of element balance, temperature range, and linearity. For realistic evaluation, null should be determined with input grounded and also with input terminated at some finite impedance, simulating actual operating conditions.	Function of input impedance, reference voltage level, and dwell time of contacts. Average about 1 millivolt with 1-megohm input impedance. Special units go as low as 10 microvolts with 100,000 ohms input impedance, and nulls of 1 microvolt have been claimed. Null can be halved if input impedance is decreased from 1 megohm to 1,000 ohms. Signal-to-noise ratios as high as 100,000 are possible.	Critical; function of temperature, tube-characteristic matching, age, heater-voltage variations, and microphonics. Best null about 1 to 2 millivolts. Average higher than 10 millivolts. Signal-to-noise ratio less than 500.	Function of heater-voltage variations. Best possible value about 1 millivolt. Signal-to-noise ratios as high as 2,000 are possible.	As low as 1 millivolt. Function of line harmonics, temperature, and input impedance. High reference frequencies give high nulls. Signal-to-noise ratios as high as 8,000 are possible in silicon modulators.	Below 1 millivolt. Function of input and output impedance. Signal-to-noise ratios higher than 2,000.	As low as 10 millivolts. 500 is maximum signal - to - noise ratio.	As low as 200 microvolts. Function of temperature and carrier frequency. Signal - to - noise ratios of 3,000 are possible.
DYNAMIC RANGE	Given in db and defined as the ratio of maximum output voltage to the carrier content of the null. Maximum output is determined within prescribed linearity limits, since dynamic range does not necessarily denote signal-to-noise ratio. Intermodulation distortion, premature saturation, unbalance, and high null affect dynamic range. Standard servomotors, with dynamic range between 30 and 35 db, should set performance limits in this respect.	100 db possible.	Less than 40 db.	50 db possible.	50 to 60 db; function of temperature and linearity.	60 db; up to 80 db possible within a restricted temperature range.	40 db maximum.	50 to 60 db.
POWER OUTPUT	If succeeding stage is a high-impedance voltage-operated device, modulator power output is not of prime importance. But if it is a semiconductor or magnetic amplifier, some power limitations may be imposed.	Ranges from 6 to 100 milliwatts. Should be kept small to increase life expectancy of unit.	High power output possible.	A few milliwatts.	Should terminate to high-impedance load, preferably higher than 100,000 ohms. Output load critical on silicon diodes.	Limited due to critical loading characteristics.	Loads between 200 and 400,000 ohms are possible.	A few milliwatts.
DISTORTION	There are two types of distortion: **Harmonics** — Even or odd, depending on modulator type. Main effects are some carrier-frequency phase shift, saturation of ac amplifier, and restriction of intelligence carried by output. Filtering is most effective remedy, although it introduces additional time delay in system. Band-pass filter, centered on carrier and with low Q to pass maximum modulated frequency without distortion should be used. At best, filter should be compromise between harmonic rejection and bandwidth restriction imposed on modulated frequency. **Sideband and intermodulation** — Caused by interaction effects of carrier with input or output. Nonlinear type with no effective remedy. Common in modulators using semiconductors. In some cases a function of input level and impedance. Most pronounced effects are dynamic-range restriction and nonlinear operation of modulator.	Square-wave output. No intermodulation distortion present since input doesn't interact with carrier.	Sine-wave output, distortion mostly second harmonic. Intermodulation a function of input level.	Square or triangular waves are most common.	Output can be square, triangular, or sine wave. Distortion mostly second and third harmonic. Some intermodulation distortion present.	Mostly third harmonic.	Output substantially a sine wave; maximum distortion 20 percent.	Substantially a sine wave; some second harmonic.
LINEARITY	Graphically, theoretically linear output is represented by straight line of independent slope, rotated about origin until best correspondence is achieved with actual output curve. This type of zero-based linearity is most applicable in servo work, since output is usually centered around null. Linearity effects depend on type of servo. In null-seeking types it has some secondary effects, especially when modulator is in servo-amplifier forward path. When modulator is used in secondary feedback loops, or in rate servos, linearity becomes more critical.	Better than 0.1 percent.	1 to 2 percent at low levels.	1 percent maximum.	Up to 1 percent for good dynamic range.	Better than 1 percent at low levels. Junction units give better linearities than point-contact units.	2 percent average. 1 percent or better possible for limited dynamic range.	Up to 1 percent for limited input levels.

	SPECIFICATIONS	GENERAL REMARKS	Choppers	Vacuum tubes	Vacuum diodes	Diodes	Transistors	Magnetic	Photocells
OUTPUT CHARACTERISTICS	SYMMETRY	Output should be bidirectional and symmetrical about zero axis. This symmetry condition restricts classes of modulators that can be used in servo applications. Lack of symmetry means nonlinear operation, affecting dynamic stability of servo.	Average about 3 percent. 1 percent is possible.	5 to 10 per cent depending on operating level.	About 5 percent.	Good; depends on degree diodes are matched. Affected by temperature.	Good	Good; affected by high temperatures.	Good for limited input range only.
	SATURATION	With large input signal, modulator saturation should be symmetrical to avoid large phase shifts, gain collapse, and nonlinear effects. Recovery time from saturation should be small, with no "memory" or hysteresis contributing serious time delays. Symmetrical saturation can be used as a limiting means.	Zero recovery time.	May exhibit nonlinear saturation.	Some clipping at high levels.	Symmetrical saturation; no recovery effects.	Recovery time may be appreciable for overrated inputs.	0.2 percent of excitation. Nonsymmetrical at large input levels.	No effect.
	EFFICIENCY	Defined as ratio of ac output to dc input; can be given as voltage or power efficiency. Ranges from 5 percent to higher than 100 percent, with most cases below 25 percent. Not important criterion, since ac amplifier will compensate for usual loss.	Up to 100 percent, depending on input form.	3 to 10 percent without using gain.	40 percent.	Up to 50 percent.	Up to 60 percent.	50 percent normal.	20 to 70 percent. Low at low temperatures.
	STABILITY	Defined as constancy of modulator gain as function of time. Usually measured in volts or watts referred to input. Gain drift is usually caused by unbalance due to temperature variations. Not too critical for error signal modulation applications.	As high as 10^{-16} watts. Input impedance higher than 20,000 usually gives better results.	Critical.	Function of filament-voltage variation. 10^{-10} watts possible with special precautions.	As high as 10^{-10} watts reported in some silicon diode modulators.	Comparable to diodes over limited temperature range.	Average 10^{-9} to 10^{-12} watts. Stabilities of 10^{-18} watts possible with second - harmonic modulator over very restricted bandwidth.	Sensitive to temperature.
	PERCENT OF CARRIER PRESENT AT OUTPUT	Since carrier-suppressed modulator is required as a means of producing side bands, percent carrier at output should be limited. In most modulators some carrier is always present at output, due mainly to circuit unbalance or degree of isolation of various modulating elements.	Can be as low as 1 microvolt at low impedance levels.	Possible to achieve level of 50 db below maximum output.	Possible to achieve 60 db below maximum output.	Less than 0.1 percent		Less than 0.1 percent.	Less than 0.5 percent.
	OUTPUT FREQUENCY	Since ac amplifiers and servomotors are carrier-operated devices, modulator-output frequency should be mostly fundamental. The even or odd harmonics are usually by-passed in amplifier with band-pass filter having zero phase shift at carrier frequency and relatively low Q to avoid high rates of phase changes if carrier-frequency drifts.	Fundamental.	Fundamental or second harmonic.	Fundamental.	Fundamental.		Odd or even harmonic depending on bias requirements.	Fundamental.
DYNAMIC RESPONSE	MODULATION	Modulator should have response considerably wider than expected overall system response to prevent additional lags that could restrict the system's useful bandwidth or even result in dynamic instability. In secondary loops operating over restricted bandwidth, modulator frequency response assumes secondary importance. Usual output is half-wave. Although it requires some filtering (adding a time delay) and contains only half the signal intelligence, it is easier to generate. Full-wave gives most efficient operation, requiring no filtering, but is more difficult to attain and usually requires two half-waves in push-pull, resulting in serious balance problem.	No time or phase delays up to 20 percent of carrier frequency.	No time or phase delays.	No time or phase delays.	Greater than 20 percent of carrier frequency.	Greater than 20 percent of carrier frequency.	Depends on gain and output load with linear input impedance. It can vary from 1 cps to 10 cps.	Greater than 20 percent of carrier frequency.
	CARRIER	**Phase shift** — Output should be in phase or in quadrature with carrier. Latter is preferred, since it eliminates problem of eventually shifting amplifier ac voltage 90 deg for maximum servomotor output. In addition, ac phase-shifting results in amplitude attenuation, asymmetrical phase rates, and time lags. Phase shifting motor reference should be secondary choice, since phase shift and motor voltage will be function of motor speed. Modulator phase shift should be constant and independent of input level or impedance. **Phase drift** — Drift of as much as ±10 percent has only secondary effect on motor output torque. However, if modulator output is summed with other signals, phase drift should be minimized.	Phase lag exists primarily because of mechanical inertia of unit. Varies from 20 to 100 deg. RC networks can correct phase shift provided circuits have low Q and unit's impedance doesn't vary much from stand-still to running condition. Phase shift is largest at higher carrier frequencies and/or lower temperatures. Phase drift is function of metal fatigue and temperature change. Varies ± 2 deg from −65 to +100 deg C.	Any phase shift possible in some types. It is function of input level. No phase drift.	Constant phase shift. No phase drift.	No phase shift or drift.	No phase shift or drift.	0 to 180 deg ±10 percent.	No phase shift or drift.

EXCITATION	FREQUENCY RANGE	Carrier frequency selected depends on availability of electromechanical components capable of operating on that frequency, and on required modulated frequency. Maximum modulated frequency is usually about 20 percent of carrier frequency. Beyond this, severe intermodulation may develop, with some loss of signal intelligence. Carrier-frequency range of present modulators covers a bandwidth from 60 cps to 10 kc. Modulator should perform satisfactorily with ±10 percent carrier-frequency variation. Carrier-frequency stability may affect null output, and will introduce phase shifts especially if high Q filters are used.	0 to 3 kc. Usually limited to range between 25 cps and 1 kc. Higher frequencies result in higher nulls.	10 kc or higher.	Up to 10 kc.	25 cps to 10 kc. Higher frequencies result in higher nulls.	Up to 10 kc with 1 millivolt null.	10 cps to 10 kc.	60 cps to 1 kc. Lower frequencies produce lower nulls.
	VOLTAGE	To assure good switching action, voltage level should be several times maximum output. Level depends on breakdown of elements. Excessively high reference voltage may adversely affect reverse saturation current of modulator, a case common in semiconductors. In addition, balancing problems are aggravated and null is increased. Low-output modulators should use a low reference voltage. Excitation is usually applied to modulator through isolation transformer to prevent grounding problems and isolate carrier from input or output. Since voltage variation effects null level, some regulation is desirable.	From 6 to 110 volts; usually 6.3 volts. Voltage should be kept low since it directly affects null level. Balance source to ground gives lower nulls.	6 to 10 volts usually applied to cathode or secondary grids. Can be made high.	As high as possible (compatible with element breakdown) to assure complete cutoff and carrier absence from input.	6 to 120 volts. Depends on maximum power dissipation capabilities of diodes.	About 1 volt required for switching, depending on transistor rating.	6 volts average.	115 volts.
	WAVEFORM	Sine wave most common, although other waveforms, such as square waves, pulses, etc., are also used at expense of increased complexity. Harmonic distortion may adversely affect modulator null, especially semiconductor and magnetic types.	Sine, square, or pulse wave. Should be symmetrical to make sure output waveform is symmetrical.	Critical since it affects null and symmetry.	Square wave preferred or sine wave of large amplitude.	Critical since it affects null. Square wave preferred but sine wave acceptable.	No serious effect on null.	No serious effects.	No serious effects, except some increase in intermodulation distortion.
	POWER	Varies from few milliwatts to about 3 watts. In some magnetic modulators current drain is nonsinusoidal and may affect other components in system (resolvers, synchros, etc.), especially if power-supply regulation is poor.	From 200 milliwatts to 2 watts.	A few milliwatts.	A few milliwatts.	Up to 100 milliwatts.	About 10 milliwatts.	From 5 milliwatts to 1 watt.	From 300 to 500 milliwatts.
	SOURCE IMPEDANCE	High or low source impedance is specified, depending on whether current or voltage source is used at input. Low source impedance exhibits better regulation and balance, and reduces harmonic content of null output.	Depends on technique used for carrier-phase shifting. Low source impedance is preferred.	Independent parameter.	Usually low; function of back and forward resistance of diode.	Should be low.	No serious effect.	Low for best results.	Low for best results.
LIFE		Operating and shelf life. Reliability figures.	Most critical spec. Function of carrier frequency, environment, and especially operating level. Failure usually due to contact deterioration. Guaranteed life varies from 1,000 to 15,000 hours depending on intended application and operating conditions.	Tube life.	Tube life.	Good; at least 10,000 hours.	At least 10,000 hours if operated within power rating of transistor.	Greater than 10,000 hours.	Limited due to sputtering of neon lamp cathode. Greater than 10,000 hours.
COMPLEXITY		Are bias, B-plus, or filament supplies necessary? Are additional transformers and balancing potentiometers required? What are maintenance problems? Is special carrier waveform or source impedance required? Must critical components be matched, and is their unbalance with temperature important? How about space and weight?	For very low noise levels special input transformers are required. Special problems for reducing electrostatic and electromagnetic noise. Reference voltage may require balancing to ground.	May need balancing potentiometers; also some bias for minimum null. Requires B+ supply.	Requires balancing for minimum null unless matching process is used.	May require bias for minimum null and good symmetry; also matching pair of diodes.	No bias circuits or special matching. Reference transformer may need isolated secondaries. Requires B+ or B− supply.	No balancing potentiometers or critical matching. Regulated bias supply needed for fundamental frequency-type modulator; otherwise null and drift are affected. Reference voltage is also critical.	Power line may have to be isolated. B+ required for neon lamp.
TEMPERATURE		Rise, ambient, and storage.	−65 to +100 deg C. Special units can go as high as 200 deg C with sacrifice in noise and life.	−65 to +100 deg C. Drift will vary depending on other components used.	−65 to +100 deg C. Drift will vary depending on other components used.	Germanium up to 75 deg C and silicon up to 100 deg C with no noticeable adverse effects.	−65 to +75 C with no serious effects.	−65 to +100 deg C. Drift is serious when temperature varies widely.	−80 to +100 deg C possible. Critical factor in some units.

Analyzing an Arc Furnace Control System

Power costs in the modern electric arc furnace have reached the point where even a small boost in efficiency means a significant savings in dollars. Very often this boost in efficiency can be brought about by a careful analysis of the control system.

This article discusses the general requirements of any automatic electrode control system, putting particular emphasis on an electrohydraulic system. An analysis of this system is made and the results checked against measurements made on an existing system. Most errors are due to certain assumptions and approximations made in the analysis, but the results are sufficiently accurate to determine system parameters for the desired loop gain.

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After a relatively slow incubation period, the electric arc furnace, Figure 1, has started a climb toward preeminence in the melting of steel. Modern furnaces as large as 24 ft in diameter melt 200 tons of metal in one heat. With 24-in. electrodes, arc currents often run over 40,000 amp in each of three phases. As power station capacities increase, it is expected that much of the steel now made in open hearths will eventually be produced in electric arc furnaces.

Automatic control of arc furnaces presents some interesting problems. The most challenging of these involves the arc itself, a unique phenomenon which must be thoroughly understood before a system analysis can be made. Although the arc has been known and studied for almost 100 years, information suitable for control analysis has been relatively scarce. Some excellent papers have been published recently, however, and these have added considerable pertinent information [1, 2, 3]. With this information the control problem can be attacked on a theoretical basis. Admittedly, the approach is highly simplified, but it is a start.

The control system

The process consists of an alternating-current arc drawn between a movable electrode and a metal charge. Radiant heat from the arc is the principal source of energy for melting the metal. This heat is controlled by adjusting the length of arc. In most cases the furnace uses three-phase current with an arc in each phase.

Figure 2 shows a block diagram of a typical system. Measurements of arc current and arc voltage are added algebraically and the difference applied to an amplifier. The set-point is reached when this difference equals some predetermined value. When an error exists, the amplifier energizes an actuator (electric or hydraulic), which drives the electrode up or down, depending on the required correction.

The set-point is applied implicitly—i.e., it results from the balancing of the two feedback signals—and is adjusted by varying the arc current signal which is fed back. The bias signal included in the controller drives the electrodes away from the molten metal in the event of an electric power failure. Because the control seeks to maintain a fixed relation between current and voltage, this type of system is sometimes referred to as "impedance" control.

System requirements

The automatic electrode control system must maintain a constant heat input to the furnace despite extreme and often violent load fluctuations. As soon as melting begins there is sudden and frequent shifting of the metal charge. To follow these shifts and still maintain the arc, the electrodes must respond rapidly. Even after the metal is molten the arc presents an erratic, continually changing phenomenon. The system thus must be capable of controlling a highly unstable process.

Fast response and high electrode velocity are of paramount importance. Response speed is neces-

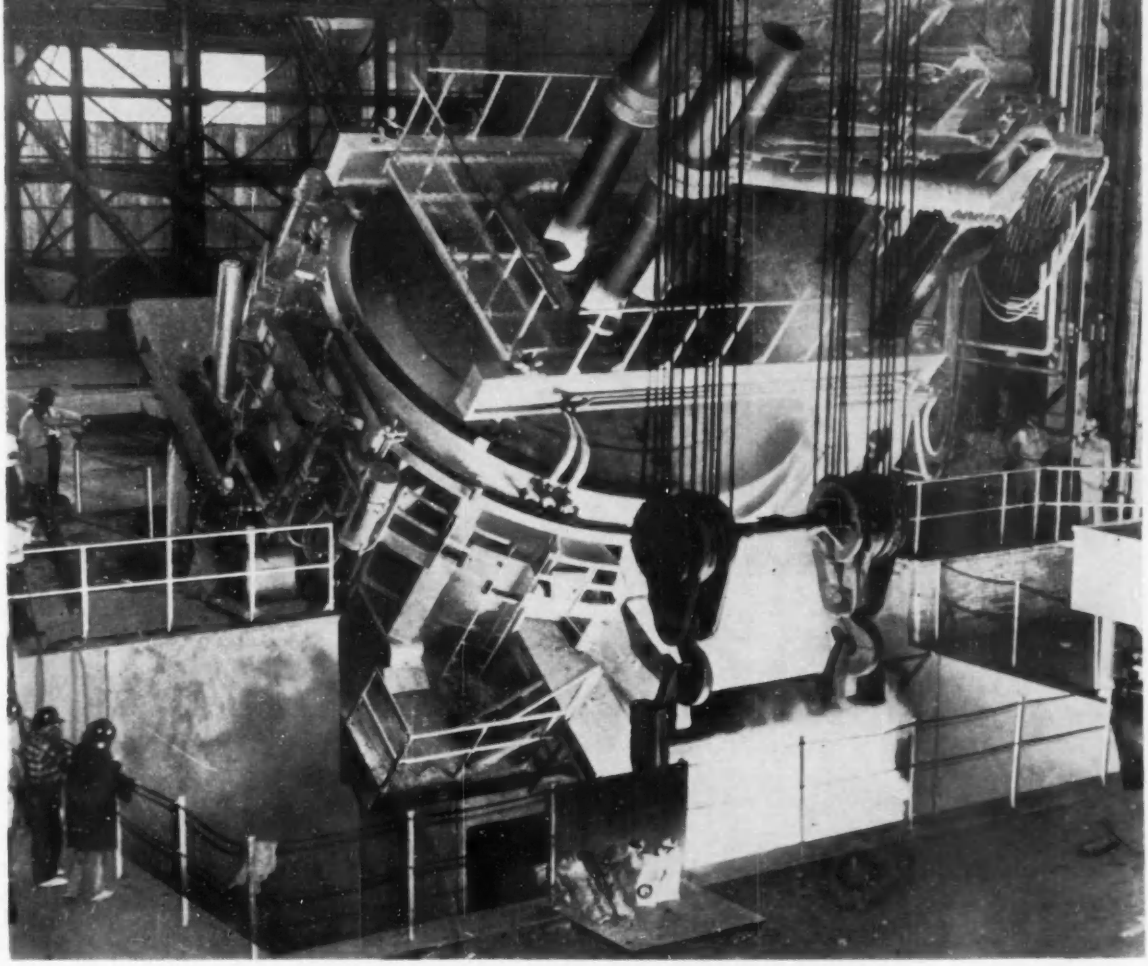


FIG. 1. Huge Lectromelt arc furnace, electrodes raised, tilts into pouring position.

sary in view of the rapidity of load variations. But even with the best control systems, response is not fast enough to prevent periodic loss of arc, particularly at the beginning of the melt. When the arc is lost the electrodes must be driven down until the arc is restruck. High-electrode velocity minimizes this "off time" and thus increases efficiency.

The metal charge acts as a common neutral or common electrode for each of the three phases involved and presents a problem of interaction among the three control systems. A change of arc length in one phase affects the current in the other two phases. There was considerable instability in early electrode control systems which used automatic current regulators. Later developments showed that much of this instability could be eliminated by using both current and voltage as measured variables. Such an arrangement also provides a more sensitive indication of arc length change than either variable taken individually.

Arc characteristics

Most steel-melting furnaces use alternating current: however, it will be helpful first to examine the

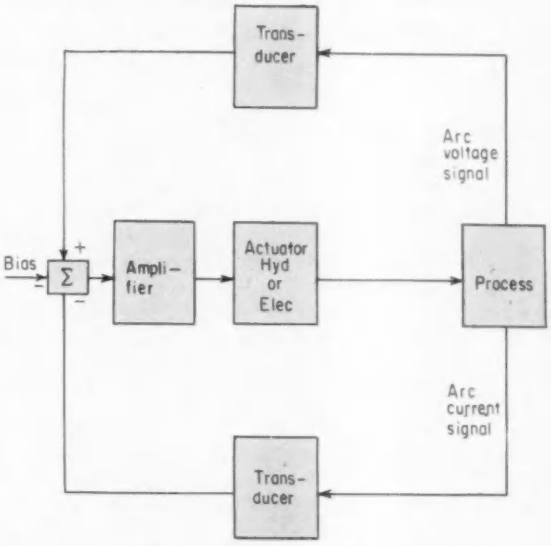


FIG. 2. Block diagram of typical arc-furnace control system.

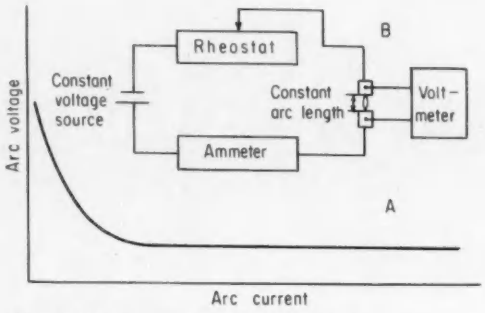


FIG. 3. A—Characteristic curve for dc arc. B—Circuit used in developing this curve.

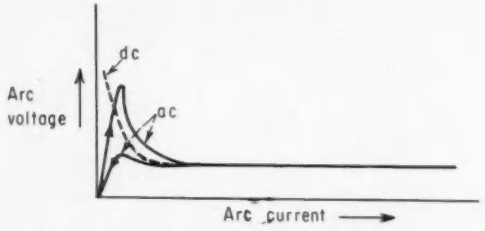


FIG. 4. Characteristic curve for ac arc.

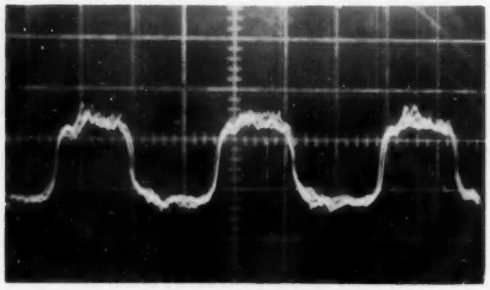


FIG. 5. Oscilloscopic picture of arc voltage waveform.

characteristics of a dc arc. Figure 3A illustrates a typical volt-ampere characteristic for a dc arc as obtained with the circuit of Figure 3B. Source voltage and arc length are held constant while the series resistance is changed. This characteristic is hyperbolic in the lower current region. Ayrton[4] states the equation for this curve as

$$V = A + BL + \frac{C + DL}{I} \qquad (1)$$

where: V is arc voltage, L is arc length, I is current, and A, B, C, and D are constants.

In Figure 4 the path of one-half cycle of an ac arc is plotted. The broken line simply repeats the dc characteristic for an arc of the same length. In the small-current region a certain amount of hysteresis exists—here the ac departs from the dc curve. In the high-current region the ac becomes essentially constant voltage. This may be seen in the picture of arc voltage, Figure 5. The flat top of the wave shows that most of cycle is spent in the constant-voltage region. Since this is often the case in furnace operation, Equation 1 can be simplified. Assuming I in Equation 1 is large,

$$V = A + BL \qquad (2)$$

Assuming further that the hysterersis effect is small, this same equation may be applied to the ac arc. For a systems analysis, the transfer function must show the change in arc voltage per unit change in arc length. Thus:

$$\frac{dV}{dL} = B \qquad (3)$$

where B is the gain factor for arc voltage.

To obtain the gain factor for arc current the impedance of the power circuit must be considered. Using the stated assumptions for arc voltage, the gain factor for arc current is approximately

$$\frac{dI}{dL} = B\left[\frac{1}{\pi R}\right]\left[\tan\theta\left(1 - e^{\frac{-\pi}{-\tan\theta}}\right) - \pi\right] = K$$

where θ is the short-circuit phase angle, R the short circuit resistance, and K is a constant.

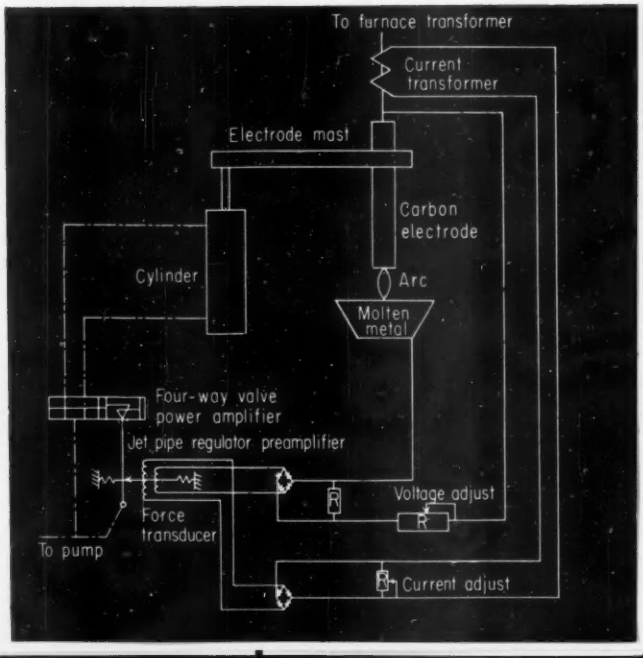
On the basis of the stated assumptions, representation of the arc reduces to gain factors B and K.

Typical controller

As an example, consider an electrohydraulic arc-furnace control system, Figure 6. In this system the electrode is positioned by a directly connected hydraulic ram. The control amplifier consists of a jet-pipe relay "preamplifier" and a four-way valve "power amplifier". Measured variables are arc voltage and arc current.

Voltage and current signals are measured and summarized in a moving-coil force transducer. This transducer operates like a dynamic loud-speaker where coils of wire move in a permanent magnet

FIG. 6. Typical electrohydraulic arc-furnace control system.



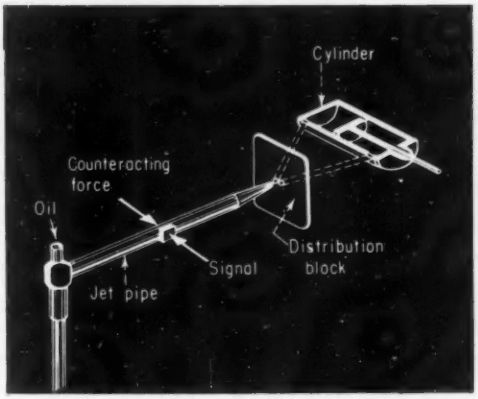


FIG. 7. Operation of the jet-pipe relay.

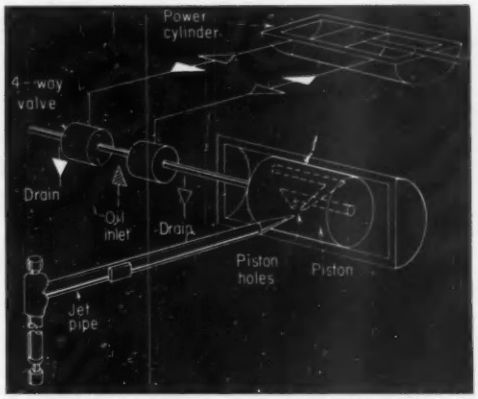


FIG. 8. Schematic shows four-way valve actuated by jet pipe relay.

field. Force from this transducer displaces the jet-pipe relay.

The jet-pipe relay changes a small displacement into a large hydraulic pressure differential. The jet pipe, a hollow rod about 9 in. long, is pivoted at one end, Figure 7. Oil pressure applied at the pivoted end causes a stream of oil to emerge from the nozzle end. This stream is directed at a distributor block having two closely spaced holes. When the stream impinges directly between the holes the recovered pressure in each hole is the same. Displacement of the jet pipe toward one hole causes a pressure differential, which may be used to move a hydraulic cylinder.

Normally, oil flow from the jet pipe is insufficient for arc furnace applications. For this reason a four-way valve, capable of controlling large amounts of flow, is added to the system. This valve is operated directly by the jet-pipe relay and a unique follower mechanism. The holes into which the jet-pipe stream flows are located in the piston of a small cylinder, Figure 8. Passages lead from these holes to opposite ends of the cylinder. When the jet pipe is displaced, pressure at one end of the cylinder rises, causing the piston to move until the pressures at each end are equal. Equal pressures occur only when the stream is centered between the holes. Thus the piston, and the four-way valve directly coupled to it, follow the movement of the jet pipe. Oil flow through the four-way valve is directed to the ram, which positions the electrode.

System analysis

Despite several nonlinearities in the system, a rough estimate of expected performance can be obtained from a linear analysis. This is done by making certain approximations for the nonlinearities.

The analysis follows standard methods. Transfer functions obtained for each of the system components are combined and an analysis made of them to show optimum loop gain and expected dynamic performance. These data may then be used for determining system parameters as well as maximum possible electrode velocity.

Transfer functions for the jet pipe relay and four-way valve have been derived previously[5]. The jet pipe, a spring-mass system with damping, is described by a second-order response with a peak at about 25 cps. The valve follows the jet pipe with a single-order response having a break point of about 15 cps.

The relation between cylinder-rod velocity and servo-valve displacement is nonlinear. By considering small displacements only, a second-order transfer function may be derived[6] (under certain conditions a first-order approximation is sufficient). In any case, use of a large cylinder area and elimination of air from the hydraulic system can make this time constant small. In arc-furnace applications a time constant of 0.01 sec can be obtained easily.

The time constants of the current and potential transformers and moving coil are usually insignificant compared to those of other components and may be ignored. These devices then contribute only gain terms in the analysis.

Severe overshooting of the electrode following a rapid correction may cause electrode breakage or loss of arc. It would appear reasonable, therefore, to choose a value of gain which would give maximum speed of response with no overshoot. When the optimum gain has been determined, system parameters may be chosen. Economic factors, as well as various limitations in components, will dictate a choice of maximum electrode velocity.

At this point the expected dynamic response and maximum electrode velocity are known. A revision in cylinder area, valve size, pump capacity, or operating pressure may then be made.

Analytical vs. measured performance

Measurements were made on an existing system to determine the accuracy of the analysis just described. Because several approximations were made

in this analysis, and because conditions in the furnace change considerably during the melt, an exact agreement was not expected.

Voltage gain was measured with the test circuit shown in Figure 9 and potentiometer voltage, proportional to electrode position, applied to the horizontal input of an oscilloscope. Vertical input was arc voltage. Moving the electrode at a constant velocity produced the oscilloscopic picture shown in Figure 10. The slope of this pattern was roughly arc voltage gain, in volts, per inch of electrode travel. Several such measurements made with carbon electrodes and molten iron at various stages of the melt produced gain values ranging between 10 and 30 volts per inch. This range agreed with values of B (Equation 2) found by various investigators [2, 3, 4]. The value was expected to vary, but was considered sufficient for rough analysis.

A similar measurement, using a voltage proportional to arc current, determined arc-current gain. This measurement showed values between 160 and 190 amp per inch of electrode travel for the system tested.

Time constants of the jet pipe and four-way valve were as given previously. The time constant of the cylinder and connected load was calculated as 0.008 sec. The system had a small loop gain of about unity.

Analysis of the system showed that response to a step input would be exponential with a correction of 63 percent of the total at 1 sec. The measured response, Figure 11, was about 1.3 sec. This error of 30 percent is quite reasonable, considering the approximations made in the analysis.

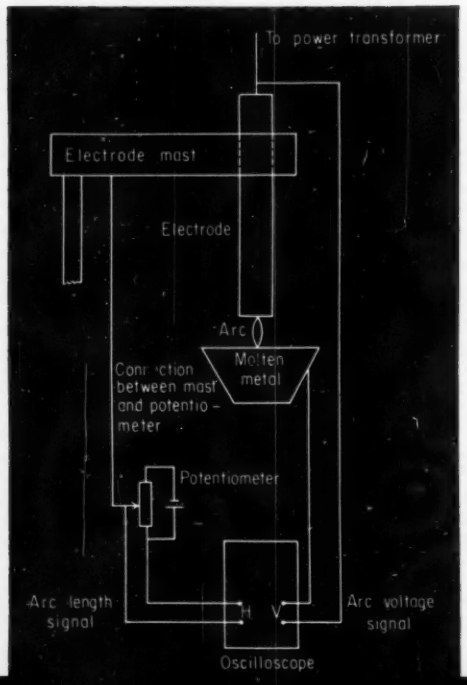
Conclusion

An analysis similar to this one for an electrohydraulic system can be made for an electrical system, and the results used to choose system parameters for optimum performance.

Although there were several approximations, the results are sufficient for practical application. The fact that conditions in the furnace itself change considerably during the melting period precludes the choice of a single optimum and makes an "average" optimum the best that can be expected without adding further complication to the system.

The very size of the larger arc furnaces means that even small improvements in efficiency will effect large dollar savings, particularly by reducing surges and fluctuations in power circuits. And it is only through a systems analysis and the choice of optimum components that these improvements are made.

FIG. 9. Test circuit for measuring voltage gain.



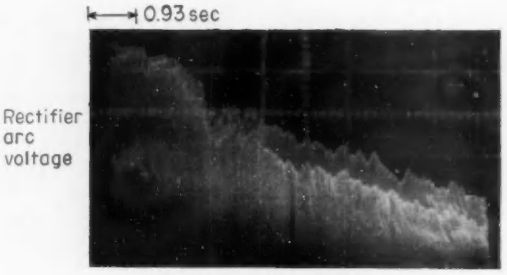


FIG. 10. Oscilloscope traces arc voltage gain.

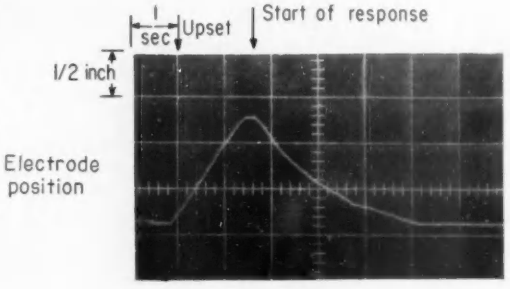


FIG. 11. Step-function response of arc furnace control.

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Effect of Integrator Motor Time-Constant on Integration Error

MARVIN P. PASTEL, U. S. Naval Postgraduate School

Motor friction, nonlinear characteristics, noise, and motor time constant can all introduce errors into motor-type integrators. For dead-reckoning systems which determine distance traveled by integrating measured velocity, this file sheet shows how to assess the error in calculated distance caused by motor time constant and saturation

for . . .

. . . step changes in measured velocity

. . . steady rates of change ("ramp") of measured velocity. See lower curve, Figure 1.

TABLE of ERROR and VELOCITY FUNCTIONS

	Step Change in Velocity, b, units/sec	Steady Velocity Change, a, units/sec; Velocity $= at$
Accumulated Error at time t	$(bKT - TV)(1 - e^{-t/T})$ (1)	$(aKT^2 + TV)(e^{-t/T} - 1) + aKTt$ (5)
Accumulated Error when $t > 5T$	$T(bK - V)$ (2)	$aKTt - TV - aKT^2$ (6)
Output Velocity at time t	$bK + (V - bK)\ e^{-t/T}$ (3)	$aKt - aKT + (aKT + V)\ e^{-t/T}$ (7)
Output Velocity when $t > 5T$	bK (4)	$aK\ (t - T)$ (8)

All initial conditions except initial indicated velocity, V, are zero.
T = motor time constant.
K = constant relating true output velocity to the input signal (voltage, current, etc.) representing measured vehicle velocity.

Integrator Without Derivative Feedback

For an integrator which has no derivative feedback, approximate an arbitrary measured velocity record with straight lines to determine the constants a and b in the table and use the tabulated functions without modification.

EXAMPLE:

Figure 1 represents a possible variation of missile velocity. K = 1 and a scales out to 10,000/70 ft/sec². Velocity is zero at zero time. Motor time constant is 10^{-2} sec.

Using function (6) in the table, because t during the time interval of interest is much greater than 5T, the second term is zero, the third term is 1/70, and the first term is 100 (t − 10)/70. Therefore, at the end of 80 sec, the error in indicated distance is 100 ft.

Function (2), T(bK − V), shows that negligible error accumulates after 80 sec because then the initial indicated velocity, V, is very nearly equal to the measured velocity.

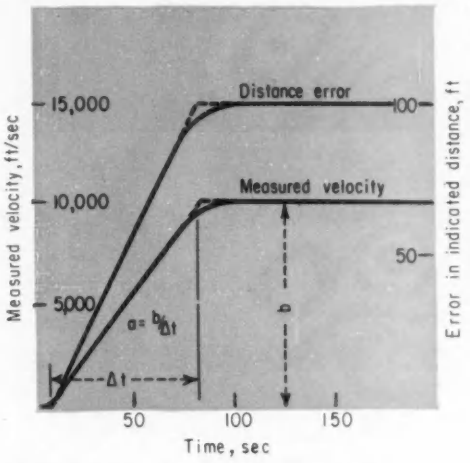


FIG. 1. Error in integration of missile velocity.

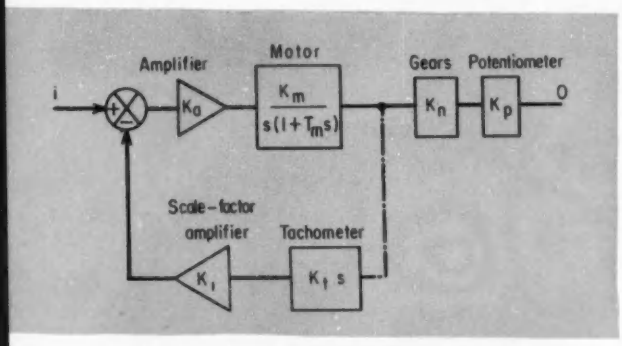


FIG. 2. Block diagram of tachometer-corrected motor-type integrator. Last portion of this file sheet shows how to calculate the entire chain of events during and after saturation of the amplifier.

Integrator With Derivative Feedback

Figure 2 is a block diagram of a servo-type integrator with tachometer feedback.

The transfer function relating indicator output to the measured signal is

$$\frac{o}{i}(s) = \frac{\dfrac{K_a K_m K_n K_p}{K_1 K_t K_a K_m + 1}}{s\left(1 + \dfrac{T_m s}{1 + K_1 K_t K_a K_m}\right)} \qquad (9)$$

If $K_1 K_t K_a K_m \gg 1$,

$$\frac{o}{i}(s) \simeq \frac{\dfrac{K_n K_p}{K_1 K_t}}{s\left(1 + \dfrac{T_m s}{K_1 K_t K_a K_m}\right)} \qquad (10)$$

Make $K_n K_p / K_1 K_t = K$ and $T_m / K_1 K_t K_a K_m = T$ to use the table when the amplifier does not saturate.

When Integrator Saturates

Because high-gain amplifiers are used to minimize steady-state system error, a step input may cause saturation. Linear operation resumes when the motor speed builds up enough for the resulting tachometer voltage to reduce the error voltage below the saturation level. When saturated, the output follows this relation,

$$o(t) = T_m K_n K_m K_p D(e^{-t/T_m} + t/T_m - 1) \qquad (11)$$

where D is the saturation output voltage from the amplifier. Then the error is

$$e(t) = bKt - T_m K_n K_m K_p D(e^{-t/T_m} + t/T_m - 1) \qquad (12)$$

And the output velocity of the integrator is

$$\frac{do}{dt}(t) = K_n K_m K_p D(1 - e^{-t/T_m}) \qquad (13)$$

The system leaves the saturated state when

$$b - \frac{K_1 K_T V}{K_n} = D/K_a \qquad (14)$$

Substituting the value of V from (14) into (13) and solving for t yields the time when the system resumes linear operation:

$$t = -T_m \ln\left[1 - \frac{1}{K_m K_p D K_1 K_T}(b - D/K_a)\right] \qquad (15)$$

Substituted in Equation 12, this value of t will give the error at the resumption of linear operation.

The value of output velocity from (13) or (14) becomes V and the input saturation limit, D/K_a, becomes b for use in Equations 1 and 2 in the table during the linear phase, that is, following the interval t, found in Equation 15.

The sum of the errors, during the saturated and linear phases, is the total error in indicated distance caused by the large step input in measured velocity.

Readers interested in the derivation of the functions in the table may obtain a copy of Research Paper No. 12, "Motor Time Constant as a Source of Integration Error", by Marvin Pastel, from the U. S. Naval Postgraduate School Library, Monterey, Calif.

Testing Metals "On-the-Fly" with Eddy Currents

Accumulating experience with eddy-current testing shows it is applicable to automatic, continuous inspection. Used carefully, the test techniques can also provide a basis for checking—and sometimes measuring—metallurgical and chemical properties such as strength and alloy composition. This makes feasible 100-percent testing of metals and metal parts right on the production machine and widens opportunities for feedback quality control.

RICHARD HOCHSCHILD, Metrol, Inc.

While calling for greater reliability in engineering materials, designers are simultaneously subjecting these materials to higher stresses in worsening environments. In this situation, the art of nondestructive testing has thrived because it makes 100-percent inspection possible. The sampling techniques necessary with destructive testing are inadequate bases for guarantying material performance.

Much development persists presently in attempts to apply 100-percent inspection to materials on the production line. Several types of instrumentation, including radiation, ultrasonic, magnetic, and electrical devices, lend themselves to such "on-the-fly" inspection. One method of special interest is eddy-current testing, which is fast, easily compatible with electronic control circuits and suitable for checking several materials characteristics in addition to seeking out mechanical flaws. Minute eddy currents induced by a radio-frequency field explore the material or part and can be made to yield information on dimensions or on the presence of flaws or faulty mechanical, metallurgical and chemical properties. By means of suitable controls linked to the eddy-current instrumentation, defective materials or parts can be rejected, sorted, or labeled. Equally important in view of today's high interest in feedback gaging and inspection, is the adaptability of eddy-current equipment for continuous adjustment of the production process through a feedback-control loop.

Several conditions affect both the magnitude of eddy currents and the paths they follow within a particular piece of metal. One such condition is the resistivity of the metal. As will be explained later in the article, resistivity depends on many microscopic (atomic-scale) phenomena. Some of these phenomena relate to the strength, hardness, alloy composition, chemical purity, and heat treatment condition of the metal part. Consequently, eddy currents may give some knowledge of these properties, frequently of industrial significance.

A second group of conditions to which eddy currents respond are discontinuities and boundaries that influence their flow pattern. Examples are cracks, holes, laps, seams and porous areas. The detection of such defects in metal objects of relatively uniform shape has been one of the principal fields of application of eddy-current testing. Here, eddy-current testing often has replaced the older methods of visual, powder-particle, penetrant, and radiographic inspection.

Eddy currents have many of the properties of a compressible fluid. They flow in certain patterns and distributions determined, first, by the design of the test coils which set up the radio-frequency waves and, second, by the frequency of oscillation of the waves. The frequency, in particular, controls the depth to which eddy currents penetrate the surface. Currents encountering an obstacle, such as a crack, are detoured around it, being compressed and weakened in the process, as illustrated in Figure 1. The current induced by the applied r-f energy in turn sets up its own magnetic field. The resultant field

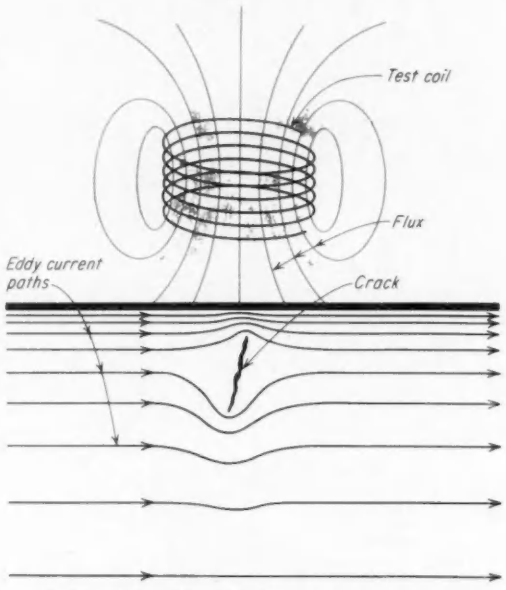


FIG. 1. Distortion of eddy-current pattern caused by a fault in a metal part.

external to the part contains information on the position, shape, and size of any discontinuity distorting the currents, and may be analyzed electronically to yield this information in useful form.

A third condition influencing eddy currents in a given part are the dimensions of that part. This has led to the availability of sensitive equipment for the determination and control of the dimensions of manufactured products such as rods, tubing, bolts, pistons, and ball bearings; the thickness of sheet, plate, strip, or foil of one metal plated or coated on another (e.g., Alclad or silverware); and the thickness of insulating coatings (paint, oil, etc.) on metal surfaces. Measurements accurate to better than a millionth of an inch can be made from one side only and without contacting the part. With equal facility, tests can be conducted either during production of a part to monitor the forming process, or after the part has been placed in operation. An application of in-use testing is the detection of corrosion in tubing, oil-well casing, and the like.

Equipment characteristics

Like X-rays, eddy currents leave no after-effect in metals. Since the test is nondestructive, the parts are as sound (or unsound) as they went in. The entire production, not just a statistical sampling, may therefore be tested, an important advantage where the quality of those parts which actually go into service must be guaranteed.

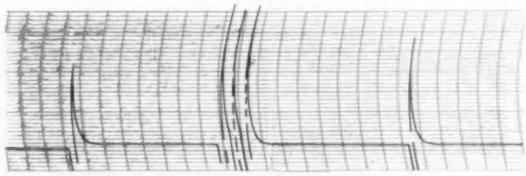
Eddy-current testing lends itself to production-line use because the operations involved are generally simple and fast. The parts to be tested may be passed by some type of motor drive, conveyor feed or by hand through or under the test coils which send and receive the radio-frequency signals. The return signals are studied for faulty conditions by electronic circuits having a built-in memory of what to accept and what to reject. The response of the test instrument can be translated into an oscilloscope pattern, a tape-chart recording, the flash of a reject light, the action of a relay which automatically expels the faulty part or paints the faulty spot, or an electronic impulse which controls parameters.

Figure 2 shows an instrument for the automatic inspection of tubing and bars for cracks, inclusions and other discontinuities. Parts to be tested roll into the unit on rails and are propelled through the cabinet by a self-contained motor drive. Within the cabinet, a solenoid-operated flaw marker automatically inks faulty areas of the part. Light and tone alarms are also provided. The compact design of this inspection system has been brought about by the use of transistors and printed circuits. Properly adjusted, this instrument can pick up a flaw as small as 0.002 in. deep, 0.001 in. wide, and 0.020 in. long in tubing at an inspection speed of 100 fpm.

Connected to the instrument but not visible in Figure 2 is a tape recorder which can be used, if

FIG. 2. Automatic instrument for detecting flaws in rods and tubing.

FIG. 3. Record of flaws in a stainless steel tube. First pip signifies a crack 0.002 in. deep. The three center pips are due to 0.014-in.-diam holes ⅛ in. apart. Pip on right indicates presence of another crack of same depth as the first.



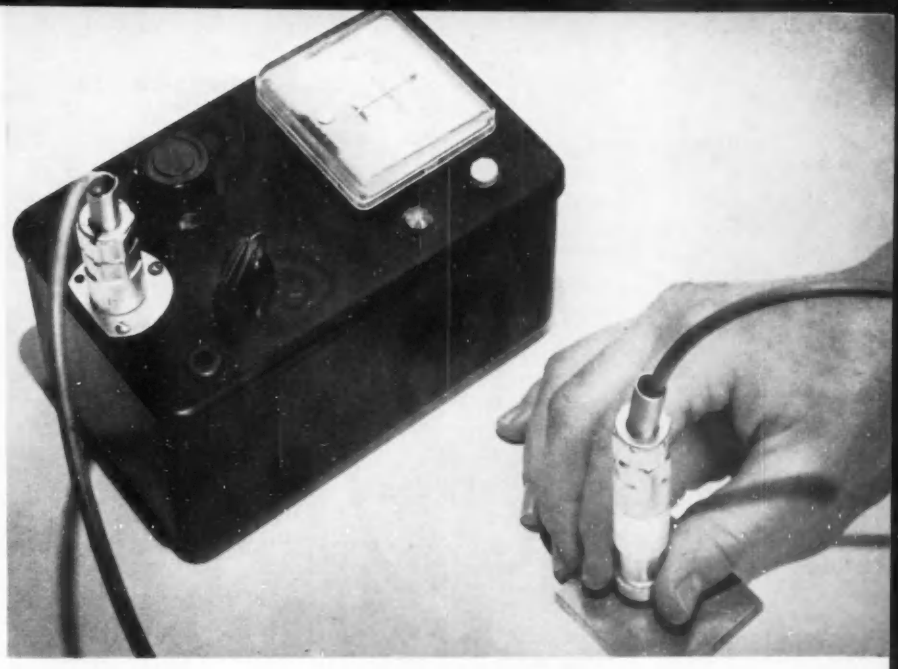


FIG. 4. Portable eddy-current tester for identifying alloys and heat treatments and checking strength.

desired, to produce a flaw record such as that in Figure 3. The trace on this tape pertains to a piece of stainless steel tubing contained a crack 0.002 in. deep (first pip); three 0.014 in.-diam holes (three close pips); and another crack 0.002 in. deep (last pip). The fact that the three holes were only $\frac{1}{8}$ in. apart is indicative of the resolution possible with this equipment.

Where parts are too large or where they are already in assembled form and cannot be brought to the equipment, eddy-current tests can be made with portable instruments brought to the part. Measuring 4 x 4 x 6 in. and weighing only 3 lb, the all-transistor and battery-operated unit in Figure 4 is suitable for identifying alloys and heat treat conditions and for making quick checks of strength, hardness or degree of carburization. Colored lights and a meter provide identification or indicate various degrees of faulty conditions.

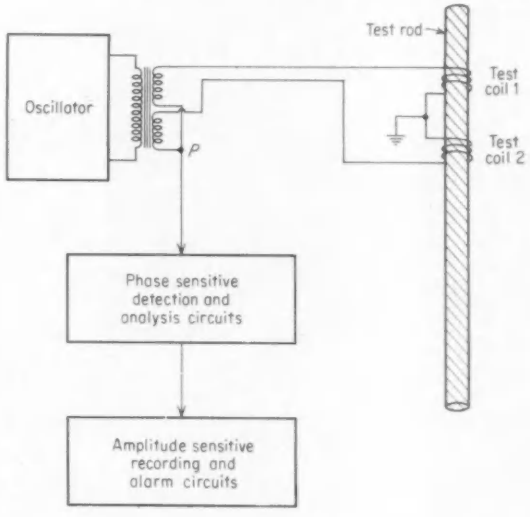
Most eddy-current equipment operates in the long wave range below the standard broadcast band and including the audio frequencies. In the testing of nonferromagnetic metals, frequencies between 1 and 500 kc, depending on application, are common. Ferrous metals are generally tested at still lower frequencies.

Operating theory

Although the mathematics of eddy-current testing tends to be cumbersome, the qualitative aspects of the theory are not difficult to grasp. A brief discussion will aid in understanding the design of modern phase-sensitive eddy-current equipment.

Figure 5 is a schematic block diagram of the instrument shown in Figure 2, which is used for flaw detection in tubing and bars. Coils 1 and 2 about $\frac{1}{8}$ in. apart surround the test part (a rod in this case) and carry an alternating current of frequency f. The electromagnetic field established by each coil sets up eddy currents in the rod. Under appropriate boundary conditions, the phase, direction, and amplitude of the eddy current at any point in the rod can be computed from appropriate formulas, provided the rod's conductivity σ, permeability μ and radius a are known. The currents follow circular loops concentric with the rod and in a plane perpendicular to the rod axis, as shown in an end view of the rod in

FIG. 5. Schematic block diagram of an eddy-current test instrument



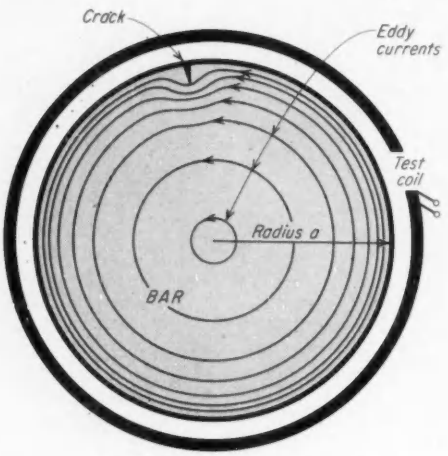


FIG. 6. End view of rod showing distribution of eddy-current paths.

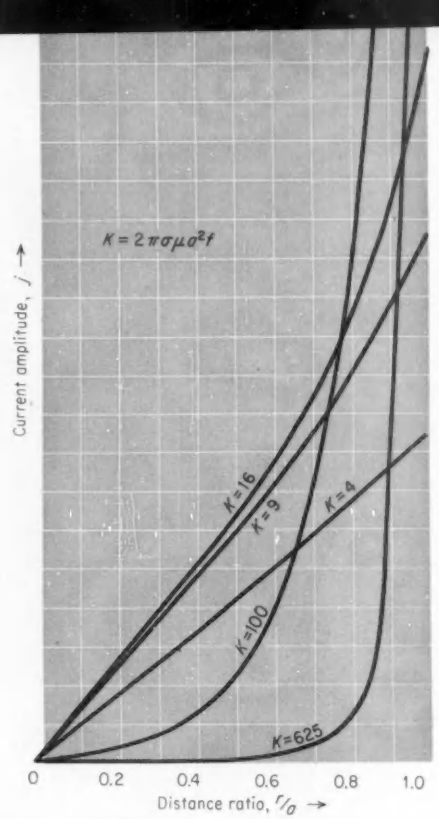


FIG. 7. Curves show amplitude of eddy currents in a rod plotted against radial distance from center. Constant K is function of rod material and test frequency.

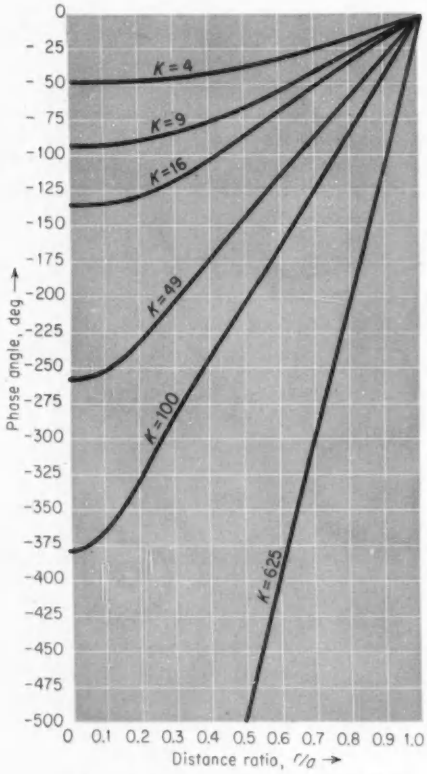


FIG. 8. Phase of eddy currents plotted as a function of distance from center for various values of K.

FIG. 9. Two-dimensional plot of amplitude and phase of bridge voltage accompanying various types of flaws and conditions.

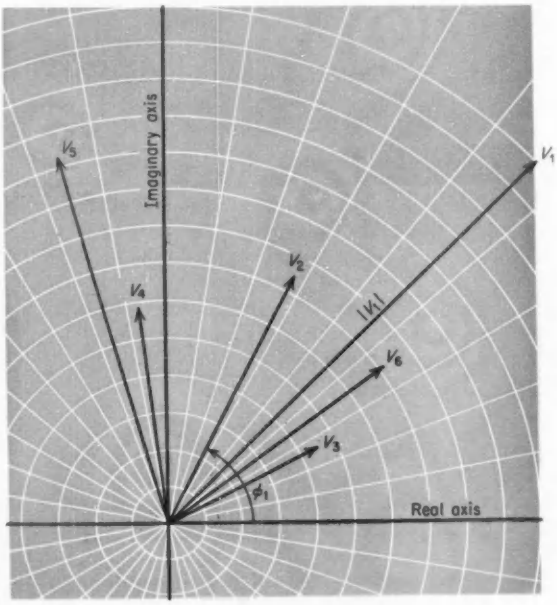


Figure 6. Note that the currents tend to be largest near the surface and die out toward the center because of skin effect.

Figure 7 shows plots of the amplitude j of eddy currents induced in a rod versus the ratio of r (radial distance from center) to a (radius of the rod). Each curve in the group relates to a different set of values of the test parameters. These values are lumped in a constant K defined by the equation:

$$K = 2\pi \sigma \mu a^2 f$$

The constant is similarly defined for the family of curves in Figure 8, representing the relationships between the phase ϕ of the eddy currents and the ratio r/a. The results are perfectly general among rods and apply to any σ or μ (i.e., any metal), any rod radius a, and any test frequency f. In fact, by the selection of appropriate test frequencies, the measurements taken for a rod of any material can be made to follow the curves of Figures 7 and 8 for any value of K. The second column of the accompanying table shows the test frequencies needed to achieve this correspondence for 1-in.-diam rods of aluminum ($\sigma = 3.54 \times 10^7$ mhos/meter and $\mu = 4\pi \times 10^{-7}$ henry/meter). The table also includes frequencies for nonmagnetic 18-8 stainless steel which, as will be noted, are 25 times higher than those for aluminum. This is because the conductivity of stainless steel ($\sigma = 1.4 \times 10^6$ mhos/meter) is only 1/25 that of aluminum. The frequencies recommended for most other common metals lie between the extremes presented in this table.

Typical Test Frequencies

K	In aluminum	In stainless
4	89 cps	2,255 cps
9	199	5,040
16	354	8,950
49	1,088	27,500
100	2,210	56,000
625	13,900	352,000

From Figures 7 and 8 three important facts can be deduced. First, skin effect becomes more pronounced with increasing K or f. Thus higher test frequencies ($K = 100$ or more) are used to inspect surface regions, while lower frequencies deepen penetration into the part at the cost of sensitivity to surface defects. Second, at any given frequency the magnitude of j falls off with increasing depth, as does test sensitivity. Hence eddy-current inspection is more suited for surface and near-surface zones than for interiors. And, third, the lagging phase angle of the current increases with depth, thus providing a basis for measuring the depth of a flaw. In addition, the phase angle behavior makes it possible to determine whether an indicated defect is actually a flaw, or a conductivity or diameter change.

The sole measurement made by the equipment is of voltage V at point P, Figure 5. With no rod within the coils, this voltage is zero because in the bridge circuit shown there is no difference in the effective impedances of coils 1 and 2. When a rod enters coil 1 only, a voltage V_1 appears at P because the eddy currents induced in the rod weaken the field of coil 1 but have no effect on coil 2. Stated another way, the effective impedance of coil 1 has been increased, thus unbalancing the bridge both resistively and inductively. The amplitude and phase of V_1 may be plotted as a vector on a two-dimensional graph, Figure 9. Amplitude is distance V_1 from the origin and phase is counterclockwise angle ϕ measured from the horizontal axis.

When the rod extends through both coils, their impedances will again be equal, provided the portions of the rod in each coil are in every way identical. Under these conditions, V drops back to zero and the instrument shows no response.

As the rod moves on during the test, a flaw may be introduced into coil 1. The flaw obstructs the normal pattern of eddy currents, modifying the field threading coil 1 and thereby causing an unbalance voltage V_2 of certain amplitude and phase to appear at P. As drawn in Figure 9, the vector V_2 represents a narrow surface crack. Theory and experience have shown that flaws of other shapes and positions, diameter changes or resistivity changes affect V differently, affording a means by which the cause may be identified. For example V_3 represents a narrow interior crack; V_4 a wide surface tool mark; V_5 a diameter variation; and V_6 a purely resistive variation associated, say, with inadequate heat treatment at that point.

By designing the equipment with channels that are sensitive only to signals of certain phases, the instruments can be made to react to particular types of flaws (e.g., cracks) and ignore other types of flaws (e.g., tool marks or diameter, permeability and resistance variations). An application of this means of selective testing is the inspection of nonmagnetic stainless steel tubing. The latter often contains internal fabrication stresses which modify the slight permeability of the tubing and cause irregular test signals far greater than those due to small flaws. Phase selectivity allows almost full occlusion of the stress signals.

After singling out and amplifying the sought-after flaw voltages, the phase-sensitive analysis circuits transfer these signals to alarm circuits and to devices producing chart records, Figure 3. The alarms consist of colored lights and a mechanical device to paint the defective spot and are not activated until the signal exceeds a certain preset amplitude. Thus flaws below a certain size may be allowed to pass if considered harmless. In the testing of small parts,

the alarm circuit may consist of a mechanical switch which automatically diverts faulty units into a reject bin, or a set of such switches for sorting parts, say to degree of hardness.

Test applications

Eddy-current equipment cannot in general provide absolute measurements of properties such as hardness, strength, chemical and alloy composition, decarburization, internal stresses, aging, and work hardening. In nonferrous metals, only resistivity can be quantitatively measured. Hence, any information on other metal properties that can be derived from an eddy-current test must be based on the effect

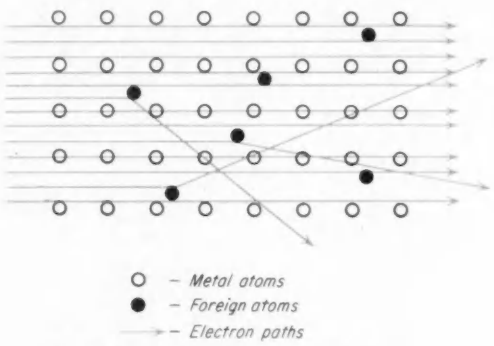


FIG. 10. Scattering of eddy-current electrons by foreign atoms in a metal lattice.

that changes in these properties have on the resistivity of the part. Changes in all of the above listed properties do alter resistivity, but this fact does not provide a unique test for any of them unless all the rest are known and constant. In ferrous metals, permeability, coercivity, and other magnetic properties are capable of absolute measurement.

Eddy currents detect *changes*—large or small deviations from a specified heat treatment, composition, strength, etc. Since such deviations are usually a concern in manufacture, eddy-current testing can perform many helpful functions in industrial process and quality control. In many cases, it can be determined accurately and quickly whether or not a part meets metallurgical specifications or whether it has a required strength. If strength were off, for example, the test would so indicate, although it might be unable to reveal the exact amount of the deviation.

Factors affecting resistivity. Eddy currents are composed of free electrons caused to drift through a metal under the influence of an induced electromagnetic field. The metal atoms are arranged in an orderly—or almost orderly—lattice structure. In their travel, some electrons collide with the atoms of the metal lattice or with impurity atoms present and are scattered, Figure 10. These electrons lose part of their energy to the lattice atoms and this energy then is dissipated in the form of heat. It may be shown that a perfectly orderly lattice cannot scatter electrons, hence has zero resistivity. Actual metals are resistive, however, because in these metals there are deviations from the perfect lattice. The deviations are caused by thermal motion of the atoms (which explains why the resistivity of metals increases with temperature) and by imperfections such as dislocations and impurity atoms. That portion of the resistivity which is not due to thermal vibrations in the lattice, i.e., that portion which does not vanish as the temperature approaches absolute zero, is called the *residual resistivity* and is the one that is of concern here.

Residual resistivity depends on factors such as:

1) foreign atoms in solid solution;
2) foreign atoms precipitated (aged) into minute particles;
3) lattice dislocations, always present, but multiplied by plastic deformation such as occurs in cold working;
4) other lattice defects or disorders, such as caused by radioactive bombardment.

Impurity atoms in a metal tend to distribute themselves randomly in the lattice and out of line with the neat rows of metal atoms depicted in Figure 10. Such atoms destroy the order of the lattice and act as scattering centers for electrons. Impurity content causes residual resistivity, which is proportional to the cross section of a given kind of impurity atom times the number of impurity atoms present per unit volume. Various impurities may have widely different effects. For example, 100 ppm of phosphorus increases the resistivity of copper by about 10 percent; 100 ppm of iron in copper raises this factor by about 2 percent. While even very small quantities of impurities are detectable by eddy-current testing it is not generally possible to determine actual concentrations if there are several impurities with different cross sections. However, the method does serve to test the overall purity of high-purity metals and to indicate deviations from specified concentrations of impurities in other than high-purity metals.

The chemical composition of process streams is sometimes controllable by eddy-current analysis because this method does not require high conductivities. For example, a change in the concentration of nitric acid in a process stream changes its resistivity; consequently stream content may be regulated by surrounding a special nonconducting section of the process tubing with a test coil and controlling the feed of nitric acid through a feedback loop.

Alloy and heat treat identification. From the electrical point of view, an alloy may be thought of as a metal with high impurity content. The analysis is complicated, however, in that the alloying atoms are rarely uniformly distributed except after a

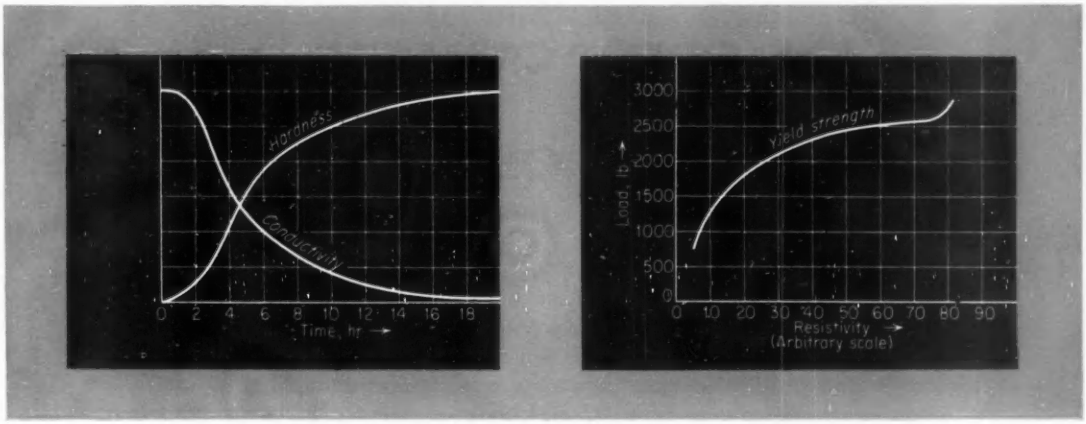


FIG. 11. Increase of hardness and decrease of conductivity in 7075 aluminum alloy as aging proceeds at 775 deg F.

FIG. 12. Yield strength versus resistivity of 7075-T6 aluminum alloy samples overaged for 10 min at temperatures distributed between 300 and 650 deg F.

"homogenizing" heat treatment to promote solid diffusion. More often an opposite type of heat treatment, involving precipitation (or aging) of certain combinations of alloying elements into extremely minute particles between crystals of the metal, is used to increase strength. Precipitation collects electron-scattering centers into islands along crystal boundaries, leaving fewer scattering centers in solution. Scattering and, hence, residual resistivity generally change on precipitation. Since it depends on the number, composition and size of the precipitated particles, the amount of scattering is determined by the choice of both alloy and heat treatment. It also depends in a smaller way on subsequent cold work which increases scattering centers.

The identification of alloys is not as hopelessly complicated as it seems, however, because certain composition and heat-treat standards have been adopted by the industry. For example, 7075-T6 aluminum alloy is given a specified heat treatment and always contains from 5.1 to 6.1 percent zinc, 2.1 to 2.9 percent magnesium, and definite amounts of other constituents. The resistivity of this material is therefore reasonably uniform from sample to sample although it differs markedly from the resistivity of certain other aluminum alloys or of the same alloy in a different heat-treat condition. Thus identification of many common alloys and of their heat-treat condition is possible.

Strength and hardness. The effects of heat treatments, such as precipitation, used to achieve strength and hardness in alloys account for the relationship between these properties and resistivity. The misfit of precipitated particles in the lattice causes internal stresses that offer resistance to the passage of dislocations, thereby hindering slip and increasing strength. They offer resistance also to the passage of electrons. Resistivity generally (but not always) increases as hardness and strength increase.

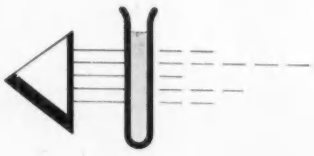
The similarity in behavior between resistivity and hardness in 7075 aluminum alloy as aging proceeds at a fixed temperature is shown in Figure 11. Figure 12 is a plot of yield strength versus resistivity for 7075-T6 samples overaged for 10 min at temperatures from 300 to 650 F. The curve shifted slightly when this experiment was repeated for samples which had been overaged for an hour at the same temperature. Thus either time or temperature of overaging must be known if absolute strength is to be determined. Deviations from a specified strength can in almost any case be detected without difficulty.

Cold work raises both strength and resistivity because the new dislocations produced serve to hinder further slip and scatter electrons. However, the effect on resistivity is comparatively small, about 2 percent in heavily cold worked copper.

Carburization

Ferrous parts such as rolled steel rod may be carburized to a greater or lesser degree for extra surface hardness. The amount of carburization and the presence of decarburized areas are conducive to measurement by eddy-current testing under controlled conditions. The carbon atoms constitute an impurity and radically alter both the electrical and magnetic properties of steel.

In summary, eddy-current testing may be described as a more powerful method than heretofore available for the industrial control of many aspects of metal quality. Its greatest difficulties arise from its being sensitive to too much rather than to too little. For this reason, it is important to design individual units of equipment so that they are sensitive only to a limited number of conditions. Such designed-in selectivity may be achieved through phase-sensitive circuits, special choice of test frequency, and special test coil design.



RADIOACTIVITY

analyzes liquids and gases

The energy of alpha, beta, and gamma rays from radioactive sources ionizes liquid and gas materials. As as a result of ionization and other effects these materials absorb part of the emitted energy. Measurements of ionization and absorption help determine gas concentration in a binary mixture, hydrogen content in a liquid, and gross density in liquids and slurries. Author Smith details the basics of this analysis technique, describes applications, and discusses hazards to exposure.

VIGO N. SMITH, Shell Development Corp.

The bombardment of liquid and gas materials with energy from a radioactive source causes ionization and other effects in the material resulting in absorption of part of the energy. Measurement of this absorption can indicate the composition of the sample material, particularly if it is a binary mixture. In practice, higher sensitivity in gas analysis is obtained by direct measurement of the ionization effect; in liquids the ionization measurement is not practicable and absorption is determined by a transmission measurement.

Radioactive sources emitting alpha, beta, or gamma rays may be used for analysis. Alpha and beta radiation consists of high-energy charged particles which interact (with the sample matter) primarily by electrostatic forces between the particles and the electrons surrounding the nuclei of the material being analyzed. Gamma radiation is an electromagnetic radiation without associated charge or mass. Its interaction with matter will be described in a later section. The net result of all three radiations are the same—absorption of energy accompanied by ionization of the sample material. Table 1 lists some salient facts about alpha, beta, and gamma emitters.

Because the radiation energy and dissipation of energy per interaction event are high compared with the relatively weak chemical binding energy in the sample, the physical state or chemical structure of the sample has no significant effect on absorption or ionization. Only the concentration and atomic or nuclear properties of the sample are important. These facts make the radiation analysis method generally nonspecific for most compounds.

Table 1 IONIZING RADIATION-SOURCES AND CHARACTERISTICS

Type of Radiation	Nature	Practical Sources For Instrumentation	Half-Life	Energy in million electron-volts (MEV)	Penetration in matter
Alpha	High energy helium nuclei; 2 positive charges; 4 mass units	Polonium 210	138 days	5.3 MEV	~1.5 in. in air
		Radium	1620 years	4.2 MEV 4.6 MEV (+gamma) 4.8 MEV	~1.2 in. in air
Beta	High energy electrons; 1 negative charge; 1/1820 mass unit	Strontium 90-Yttrium 90	19 years	0.54 MEV 2.2 MEV (maxima of continuous energy spectra)	~20 ft in air ~⅜ in in water
Gamma	Electromagnetic radiation; quanta or photons; no charge or mass	Cesium 137	33 years	0.66 MEV	~9 in. for $\frac{1}{e^2}$ = 0.136 transmittance in water
		Cobalt 60	5.3 years	1.17 MEV	~13 in. for $\frac{1}{e^2}$ = 0.136 transmittance in water
		Radium	1620 years	0.19 MEV	~7 in. for $\frac{1}{e^2}$ = 0.136 transmittance in water

USING RADIATION FOR ANALYZING GASES

Stripping of electrons from the outer electron shells of gas atoms or molecules exposed to alpha or beta radiation produces ion pairs consisting of equal numbers of positive ions and negative electrons. The ion pairs recombine within a short time to form neutral gas atoms or molecules. This action results in a dissipation of energy and therefore absorption of radiation. Measurement of absorption could, in principle, be used for gas analysis. However, the low density of gases requires a relatively long path through the sample for adequate sensitivity, and this long path results in poor source geometry and is not practical for analyzing gases.

Measurement of ionization is much more satisfactory for gas analysis. The ionization measurement is made by placing a pair of insulated electrodes in the gas and applying to them an accelerating voltage large enough to collect the ions before they recombine. By connecting a suitable amplifier and indicator or recorder in the electrode circuit, the ion current can be measured, Figure 1.

A pure beta emitter, such as strontium 90, is the best source for a practical gas analyzer. Alpha or gamma emitters could be used, but they are less satisfactory. An alpha source has a weak penetrating power, and if placed outside the chamber containing the gas its radiation could not go through the chamber wall. If placed inside the chamber, it would create danger of radioactive contamination of the sample material. (Nevertheless, a successful instrument using alpha radiation has been developed for studying diffusion processes in beds of porous catalyst carriers[1].) Gamma radiation has its drawbacks, too: small ionizing efficiency, and high penetration that requires heavy shielding for safe operation.

Theory of ionization in gases

The current flowing in the ionization chamber in Figure 1 depends on:

- type and intensity of the radiation source
- ion recombination rate
- potentials on the electrodes, and
- ionization cross-sections of the gases

If the first three of these factors are kept or assumed constant at suitable values, the current becomes a function only of ionization cross-section. The ionization cross-section then is a simpler way of stating the probability that the gas will ionize under bombardment of radiated particles. Theoretically, ion current increases linearly with an increase in cross-section. Thus, if the ionizing cross-section of individual elements in a gas is known, the corresponding relative current can be predicted.

Otvos and Stevenson[2] derived a modified Bethe theory which shows that atomic cross-section area, hence ionization current, depends primarily on an

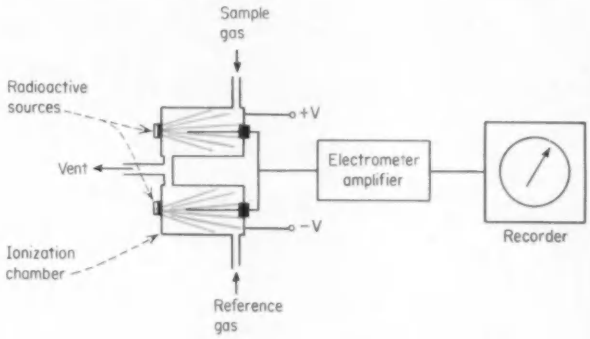


FIG. 1. Basic components of ionizing radiation gas analyzer.

atomic element's valence electrons. Table 2 shows theoretical relative cross-sections of some elements.

The molecular ionization cross-section of a gaseous compound can be calculated by finding the sum of the atomic cross-sections of individual elements in the compound:

$$M = \sum_i n_i A_i \qquad (1)$$

where M is the molecular cross-section, n_i is the number of atoms of element i in the compound, and A_i is the atomic cross-section of element i. An example: compute the relative molecular cross-section of methane (CH_4), using Equation 1 and Table 2. CH_4 has one carbon atom with a cross-section A equal to 4.16 and four hydogen atoms ($A = 1.00$ each) with a total cross-section of 4.00. Thus, the molecular cross-section of methane is 4.16 plus 4.00, or 8.16.

Table 3, right column, lists molecular cross-sections for many gas compounds computed in the same way. According to theory, the current should be proportional to the molecular cross-section of the gas compound. However, precise experiments run on actual ion currents for these gases resulted in the relative currents listed in Table 3, middle column. For the purpose of comparing theoretical and test values, the relative current and the molecular cross-section for methane have been set equal to each other at 8.16. Figure 2, a plot of the information in Table 3, shows that some gas compounds, particularly the hydrocarbons, follow the predicted linear relationship between cross-section and relative current, and that others deviate in varying degrees.

The reasons for the deviations are not too well known; they probably result from formation of negative ions in the cases of ammonia and Freon-12. Changes in shape of the ionization chamber, in the geometry of the radiation source, or in particle energy also affect relative currents to some extent

Table 2
RELATIVE IONIZATION CROSS-SECTIONS OF SOME ELEMENTS

Element	Atomic Number	Relative Ionization Cross-Section (A)
Hydrogen	1	1.00
Helium	2	0.69
Carbon	6	4.16
Nitrogen	7	3.83
Oxygen	8	3.28
Fluorine	9	2.89
Chlorine	17	11.8
Argon	18	10.9

Table 3
RELATIVE ION CURRENTS FOR VARIOUS PURE GASES AT ATMOSPHERIC PRESSURE

Gas	Relative Current	Molecular Cross-Section (M)
Hydrogen	1.47	2.0
Helium	1.88	0.69
Ammonia	4.79	6.83
Methane	8.16	8.16
Nitrogen	8.16	7.65
Carbon Monoxide	8.36	7.45
Oxygen	9.93	6.55
Ethylene	12.41	12.3
Carbon Dioxide	12.53	10.8
Argon	12.62	10.9
Ethane	14.77	14.3
Propylene	18.20	18.5
Propane	20.73	20.5
Freon-12	24.72	33.5
Isobutane	26.52	26.6
Normal Butane	26.93	26.6

and will, in some cases, change the position of adjacent gases in this scale. Actual ion current ranges from 10^{-11} to 10^{-8} amp, depending on ionization chamber size and source strength.

Analyzing gas mixtures

Just as it is theoretically possible to predict molecular cross-section of gas compounds based on atomic elements present in the gas, so is it theoretically possible to make qualitative predictions of ionizing cross-section, hence ion current, of binary mixtures of gases. The relative ion current can be found (first approximation) by adding the ion currents contributed by the individual gaseous compounds present. This may be expressed mathematically as:

$$I = \sum_i c_i i_j \qquad (2)$$

where I is the relative ion current for the mixture, c_j is the fractional concentration of gas j, and i_j is the relative ion current for pure gas j (from Table 3). To illustrate how this works: compute the relative ion current for a mixture of 50 percent CO_2 in nitrogen, using Equation 2 and Table 3. First compute the contribution from CO_2—the fractional concentration is 0.5 and the relative current for pure CO_2 is 12.53, giving a contribution of 0.5 times 12.53 or 6.27 to the current. Similarly, the fractional concentration of nitrogen is 0.5 and its pure gas current is 8.16, making a contribution of 4.08. Adding these two numbers, 6.27 plus 4.08, gives 10.35, the relative current for the mixture. To get the current for the mixture relative to pure nitrogen (8.16) it is necessary to divide 10.35 by 8.16, which gives 1.27. This agrees quite well with the experimental value, as may be seen in Figure 3.

Because of recombination and charge transfer effects, it is not always safe to rely on qualitative predictions alone. In some cases, such as ammonia in nitrogen, small concentrations of a low-current gas in a higher-current gas gave an increase in current instead of an expected decrease. A gas analyzer should therefore be calibrated against known concentrations of the binary gas mixture to obtain the true values of ion current vs. concentration.

Figure 3 shows current as a function of concentration for a number of gases in nitrogen. The solid lines refer to values obtained from calibrating with known concentrations and the dashed lines refer to predicted values. The actual curves for ammonia

FIG. 2. Relative ion current as a function of molecular cross-section.

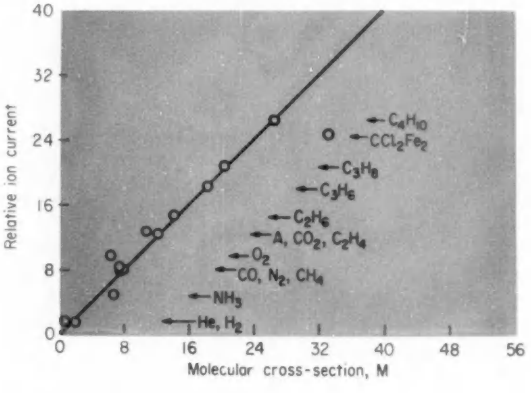
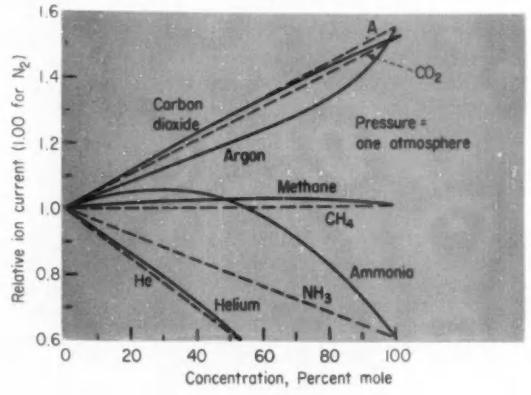


FIG. 3. Relative ion current as a function of concentration for various gases in nitrogen. Solid lines refer to calibrated values and dashed lines refer to predicted values.



and methane in nitrogen indicate the anomalous behavior mentioned above, while those for helium and carbon dioxide show an agreement with the qualitative predictions obtained from pure gases.

Measuring argon and ammonia

The most extensive use of the radiological gas analyzer in the chemical industry has been in the analysis of circulating gas in Shell Chemical Corp. synthetic-ammonia plants. The circulating gas consists mainly of unconverted nitrogen and hydrogen, with small amounts of argon and ammonia. Argon appears because it was in the air used to obtain the nitrogen for the ammonia process, and ammonia appears because of some inefficiency of the ammonia condensing system. Too much argon reduces conversion efficiency and must be bled off, though excessive bleeding wastes valuable synthesis gases. Thus maintaining argon at a suitable bleed rate assures optimum efficiency, and controlling ammonia content assures proper operation of the ammonia condensing system and proper formation of the catalyst in its early stages.

The argon-ammonia analyzer consists of:

- a self-regenerating ammonia-removal system using silica gel or a molecular sieve.
- a hydrogen-removal system using a hot palladium tube
- a measuring unit (ionization chamber)
- an electrometer amplifier
- an electronic temperature controller for the sample, and
- a separate recorder (which may be installed remotely) to chart the analyzer output

The analyzer has been built in two forms, explosion-proof for installation in Class I Group D hazardous locations, and standard (with provisions for purging with instrument air) for nonhazardous locations. Figure 4 shows the standard model, and Figure 5 is the schematic flow diagram of the analyzer and sampling system. V. N. Smith and D. J. Pompeo give a detailed description of this analyzer in Reference 3.

Since the ionization chamber of the argon-ammonia analyzer cannot distinguish the concentration of any one component in a mixture of more than two gases, it is necessary to remove interfering components from the sample stream before it reaches this chamber. The analyzer has been designed to measure the concentration of argon in nitrogen and the concentration of ammonia in nitrogen, based on data shown in Figure 3. When argon is to be recorded, then ammonia and hydrogen must be removed by the sampling system. Methane, if present, is not removed, but a zero correction is made on the basis of methane concentration (previously determined by an infrared gas analysis). When ammonia is to be measured, the ammonia removal system is by-passed so that the instrument reads the sum of argon and ammonia concentrations. Because analyzer response is substantially linear for argon and ammonia at small concentrations, Figure 3, the previously-determined argon concentration is subtracted from the argon-ammonia concentration to yield desired ammonia concentration.

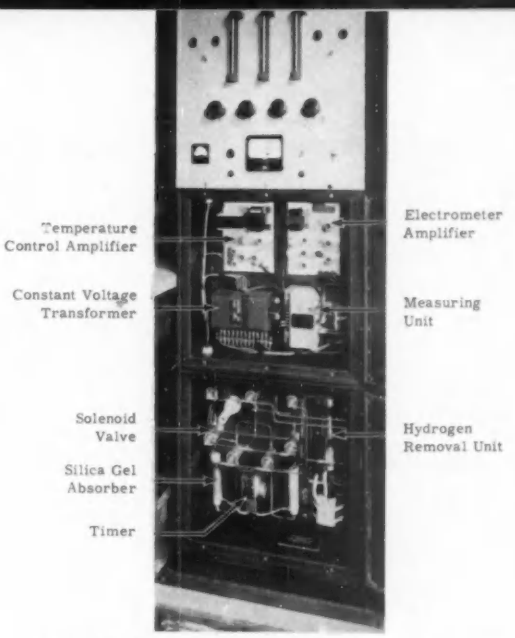


FIG. 4. The standard gas analyzer fits into a purged cabinet. The open door reveals the major components.

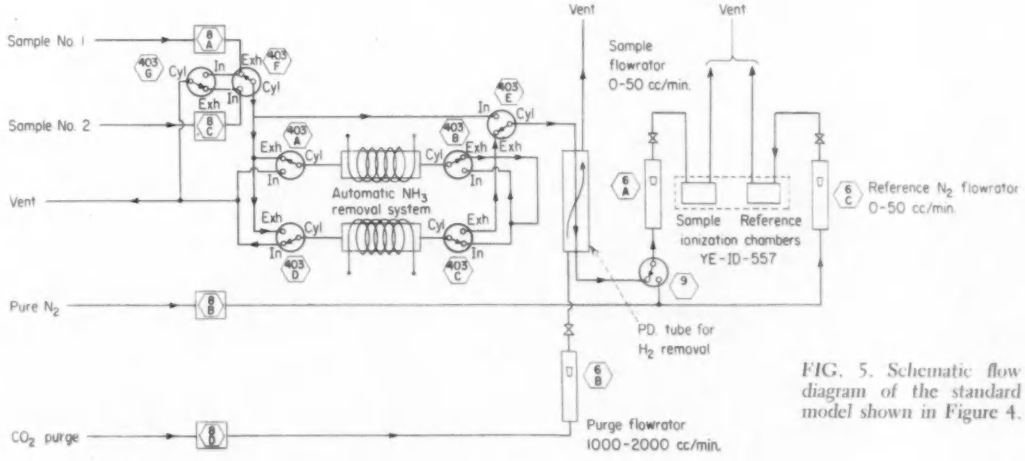


FIG. 5. Schematic flow diagram of the standard model shown in Figure 4.

Table 4
RELATIVE ABSORPTION CROSS-SECTIONS OF SOME ELEMENTS

Element	Atomic Number Z	Relative Absorption Cross-Section S	Atomic Weight a	$\frac{S}{a}$
H	1	1.00	1.008	0.992
C	6	6.80	12.01	0.566
N	7	8.17	14.008	0.583
O	8	9.55	16.000	0.597
Mg	12	12.25	24.32	0.504
Si	14	19.4	28.06	0.691
S	16	23.0	32.006	0.719
Cl	17	25.3	35.457	0.714
Ca	20	27.6	40.08	0.689
Sr	38	75.4	87.63	0.860
Ba	56	155	137.36	1.128

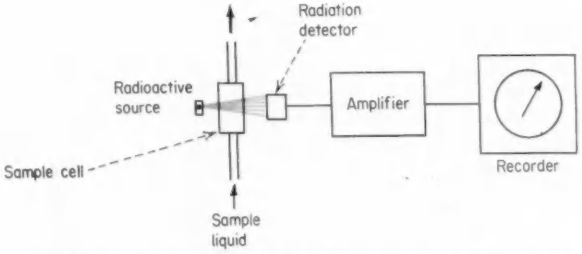


FIG. 6. Components of absorption-measuring liquid analyzer.

The analysis of liquids is made by measuring the absorption of radiation passing through a sample of the liquid. Only beta or gamma radiation sources are useful for measuring concentration or density because alpha radiation becomes completely absorbed in an extremely thin layer of liquid.

The block diagram of a simple liquid analyzer is shown in Figure 6. Here, emitted beta or gamma radiation passes through one wall of a cell, through a sample of flowing or static liquid, through the other wall, and into a radiation detector. The amplified detector signal feeds a recorder and sometimes a controller to complete the control loop.

The choice of radiation type depends on accuracy, sample condition, and availability. Beta radiation should be used where high accuracy is needed and where a side-stream sample may be conveniently taken from the main product stream. Gamma radiation suffices for applications needing less accuracy. Its high penetrating power makes possible the measurement of process-stream density right in normal plant piping, in processing vessels, and in storage tanks, and thus eliminates the need for taking a side-stream sample.

Ionization chambers, scintillation counters, and Geiger-Muller counters detect and measure radiation passing through the liquid sample. For plant-type instruments ionization chambers prove to be the most rugged, reliable, and stable detector. Unlike other detectors, which are subject to large statistical errors because of their limitation in maximum counting rate, ionization chambers allow much higher intensities from the sample, stronger sources, and thus small statistical variations in output.

Beta ray absorption

Beta particles lose energy because of:

- ionization resulting from electrical forces between the particles and atomic electrons
- radiative collisions with nuclei, which give rise to continuous radiation in the x-ray region
- scattering by nuclei or atomic electrons

All beta particles emitted from a radioactive source do not have the same energy. Rather, they have a characteristic energy distribution which, together with the absorption actions, result in an effective absorption that varies nearly exponentially with sample thickness and density.

For a fixed cell depth and a fixed incident intensity the transmitted beta particle is a function only of the sum of the absorption cross-sections, or stopping powers, of all atoms present in the cell. That is, $I = f(A)$, where I is the transmitted intensity,

$$A = \sum_i n_i S_i$$

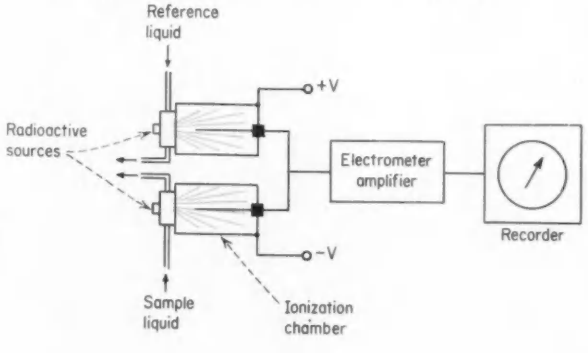
n_i is the number of atoms of element i in the cells, and S_i is the absorption cross-section of element i. The relative absorption cross-section of some elements are listed in Table 4. They apply for beta radiation from a strontium 90-yttrium 90 source.

In terms of density ρ, weight fraction w_i, and atomic weight a_i of the individual elements, the molecular absorption cross-section may be stated as:

$$A = \rho \sum_i \frac{w_i S_i}{a_i} \qquad (3)$$

The molecular absorption cross-section of benzene (C_6H_6) can be calculated, using Table 4 and Equation 3: Benzene density (at 37.2 deg C) equals 0.8607. The atomic weight of the carbon is 6 times

FIG. 7. Dual-beam radiation analyzer that measures density difference between reference and sample liquids.



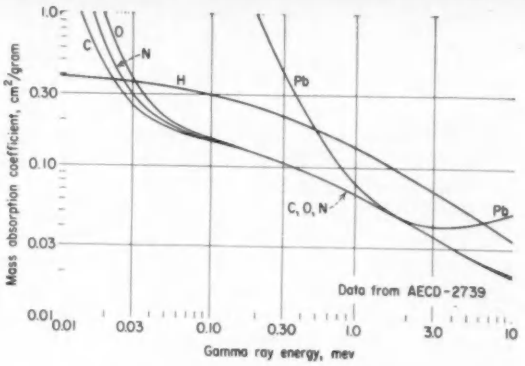


FIG. 8. The mass absorption coefficients for several elements have been plotted at various energies emitted from a gamma ray source.

12.01 or 72.06; and the atomic weight of hydrogen is 6 times 1.008 or 6.048, yielding a total atomic weight of 78.11. Therefore, the weight fraction of carbon is 72.06/78.11 and that of hydrogen is 6.048/78.11. From Table 4 the S/a ratio of hydrogen is 0.992 and that of carbon is 0.566. Putting these values into Equation 3 yields:

$$A = 0.8607\left(\frac{72.06}{78.11} \times 0.566 + \frac{6.048}{78.11} \times 0.992\right) = 0.5157$$

Reference 4 lists the total absorption cross-section for many liquid compounds.

An instrument such as the one in Figure 6 can be calibrated experimentally, using pure compounds with known absorption cross-sections. The result is a plot of output current vs. cross-section. The total cross-section of any unknown liquid can be found from this calibration curve. Knowledge of the output current in conjunction with Equation 3 can be used to determine either:

- density of the liquid, or
- hydrogen content in the liquid

Since the ratio of atomic cross-section to atomic weight S/a is very nearly the same for most of the light elements except hydrogen, and since the total weight fractions of elements in the liquid equal unity, the evaluation of the summation in Equation 3 results in an essentially constant value when hydrogen is absent. For liquids not containing hydrogen, Equation 3 then can be restated in a form that shows density is primarily a function of A: $\rho = kA$.

However, in organic liquids (those containing hydrogen and carbon) cross-section is a sensitive function of hydrogen content—the ratio S/a is nearly twice as great for hydrogen as it is for other light elements. This puts a serious limitation on instrument accuracy for most density determinations.

The exceptional S/a ratio of hydrogen does have this advantage, however: it makes it possible to determine the weight fraction of hydrogen in organic liquids. That the measurements of hydrogen content is feasible can be seen from a rearrangement of Equation 3:

$$w_h = \frac{A/\rho - S_c/a_c}{S_h/a_h - S_c/a_c}$$

where ρ is the density, S_c/a_c is the ratio for carbon, S_h/a_h is the ratio for hydrogen and w_h is the hydrogen weight fraction. Thus, the weight fraction is a function of absorption cross-section, provided density is measured by an independent gravimetric method.

Beta ray density measurement

Figure 7 is the block diagram of a dual-beam beta-ray absorption apparatus for continuous density measurements of flowing liquid samples. Beta particles from a strontium 90 source pass through a thin cell (2 to 3 mm deep) containing the sample liquid whose density is to be determined. The unabsorbed particles passing through the cell enter the ionization chamber. A similar arrangement is provided for the reference liquid, which has a density near the center of the desired range. The difference between the ion currents in the two chambers is fed into an electrometer amplifier and then into a recorder.

Ionization chambers used in the liquid analyzer for measuring radiation intensity and those used in the gas analyzer have one essential difference. Gas-analyzer ionization chambers have a fixed value of incident radiation but a changing ionization cross-section for the flowing gas inside the chamber, so that the ion current is a function of ionization cross-section. Ionization chambers in the liquid density analyzer, on the other hand, are filled and sealed with a permanent gas of known ionization cross-section, so that the ion current becomes a function only of the incident radiation, which in turn is dependent on absorption due to liquid density.

The electrometer amplifier measures differences between total currents in the order of 10^{-9} amp. Full-scale recorder deflection is obtained for changes in difference current as small as 0.5 percent of the total ion current from one chamber.

Making density measurements

For binary liquids, beta ray absorption analyzers record density with an accuracy of about plus or minus 0.0002 grams/ml. Better accuracy can be achieved by increasing source intensity and improving temperature control of the sample.

Certain limitations must be kept in mind when making density measurements of more complex mixtures. Some idea of the magnitude of density error due to composition change can be obtained by expanding Equation 3, taking into account the errors contributed by changes in each element. For instance, the greatest source of density error with organic liquids is the variation in carbon/hydrogen ratio or in oxygen or sulfur content. A change of 10 percent of the hydrogen content normally present introduces an error of about 30 times the limiting error (30 x 0.0002) in density determination. A change from a 1 percent concentration to a 2 percent concentration of sulfur introduces a density error of about ten times the limiting error.

Despite these limitations, beta ray absorption should find wide application in density measurement

and control of many materials. The output signal from the apparatus may be used to reject impure materials for reprocessing or to control directly the density of a pure product from a distillation column. Beta rays may also control density of blended oils.

Gamma ray absorption

Gamma radiation, an electromagnetic type of radiation, results in three effects as it interacts with and passes through matter:

- the photoelectric effect—primarily observed at low gamma ray energy. A gamma ray photon interacts with an electron bound to an atom, transfers sufficient energy to eject the electron, and thus annihilates the gamma ray. This results in ionization of material and attenuation of gamma ray intensity
- the Compton effect—of primary importance at somewhat higher gamma ray energy. The photon scatters elastically with a loosely bound electron. Energy difference is carried off by the electron, which produces further ionization in its path.
- the production of pairs of positrons and electrons by annihilation of the gamma rays in the field of a heavy nucleus—important only at very high gamma ray energies and with materials of high atomic number. The gamma ray energy is carried off by the two charged particles.

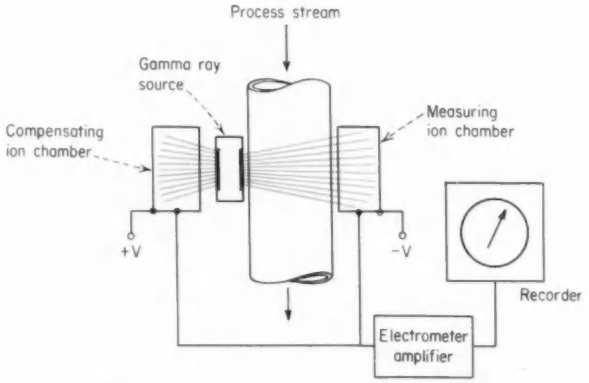


FIG. 9. Because of its strong penetrating power, a gamma ray density analyzer can be clamped directly to process piping. A typical setup is shown here.

The result of these three processes at any particular gamma ray energy and for any particular material is an exponential absorption:

$$I = I_0 e^{-\mu \rho d} \qquad (4)$$

where I is transmitted intensity, I_o is initial intensity, μ is mass absorption coefficient, ρ is density, and d is path length of gamma rays in the material. Approximate mass absorption coefficients as a function of energy for a few materials are plotted in Figure 8 from data given in an Atomic Energy Commission report[5]. For most materials of interest in the processing industries absorption is mainly due to the Compton effect for gamma rays with energies between about 0.05 MEV and 10 MEV. For materials such as lead and iron, which might be used in shielding, the photoelectric effect is still of some importance up to nearly 1 MEV. Common sources are cobalt 60 and cesium 137, which have gamma rays of energy in the range 0.6 to 1.33 MEV (see Table 1).

For gamma radiation the exponential absorption law holds quite well, and the optimum cell depth in terms of maximum absolute signal for density change ($\Delta I/\Delta\rho = \max$) occurs when the transmission is I/e. In other words the cell depth should be so chosen that at the center of the operating range on a density determination the transmission is approximately 37 percent. However, this is not necessarily the ideal criterion for optimum cell depth. Because statistical fluctuations are important at the gamma-ray intensities normally used, it may be desirable to choose the cell depth that will give the maximum signal-to-noise ratio. If maximum signal-to-noise ratio ($S/N = \Delta I/\Delta\rho\sqrt{I} = \max$) is used as the criterion for optimum cell depth, instead of maximum absolute signal, it can be shown that the optimum occurs at a cell depth giving a transmission of $1/e^2$ or about 13.6 percent. Fortunately, neither function varies drastically with the cell depth, so the choice of cell depth is not extremely critical.

Density measurement

The usual gamma ray absorption equipment designed for recording density consists of the equipment shown in Figure 9. Usually a small density span about some mean value is to be recorded. Then the current from the measuring cell, at the center of the density span, is canceled by an equal current from the compensating cell, and variations in sample density produce difference currents that are amplified and recorded. The compensating current is adjustable by changing the spacing between source and compensating cell or by inserting absorbers to match the measuring and compensating currents.

At maximum sensitivity, changes of about 5 percent of total ion current produce full-scale deflection. Total ion currents are usually between 10^{-10} and 10^{-9} amp and the span at maximum sensitivity is thus about 5×10^{-12} amp minimum. A rugged and stable electrometer amplifier is required for this measurement.

The major advantage that gamma rays have over beta rays and many other analytical techniques is that no sample need be taken from the process. Ordinarily a radiation source and a detector may be clamped directly to process piping, provided the wall is not too thick and pipe diameter is within a suitable range—2 to 24 in. The external source and detector arrangement is most common, though one manufacturer has the source mounted inside a special section of pipe. Half the pipe contains a reference liquid and the other half sample. Ionization cham-

bers surround the entire pipe section. This arrangement has the advantage of essentially 4π geometry —all gamma rays passing through the sample and reference liquids also pass through the ionization chamber and are measured.

In most cases the accuracy of gamma ray absorption apparatus is limited to approximately plus or minus 0.001 grams/ml, as compared with plus or minus 0.0002 for available beta ray absorption apparatus. The difference in accuracy is not fundamental, but results from the rather poor cell-depth geometry and low efficiency of detection of gamma rays as compared with beta rays.

An important factor is temperature control of the sample. In a large pipe ordinarily used as a sample cell for the gamma ray apparatus it is difficult to maintain close control of sample temperature. In the beta ray apparatus close control of sample temperature is relatively simple because of small sample volume and low flow rates. Another limitation on accuracy, particularly when using gamma ray instruments, is temperature sensitivity of measuring cells exposed to temperatures on process piping. Ionization chambers exhibit temperature coefficients which vary from less than 0.01 percent per deg F to nearly 1 percent per deg F depending on design and gas filling. In beta ray instruments the cells are temperature-controlled in a heated case.

SAFETY CONSIDERATIONS IN USING RADIOACTIVE SOURCES

The possibilities of exposure to or ingestion of radioactive material by operating personnel make ionizing radiation instrumentation hazardous in the plant. These hazards are new and unfamiliar to most instrument engineers. However, they are no worse, when understood, than high temperature or corrosive chemicals. One thing that should be realized is that radiation hazards are cumulative—and maximum exposure tolerances are continually being revised downward. No unnecessary exposure should be permitted, even if this exposure is well below presently-known nominal tolerances.

Direct and prolonged exposure to ionizing radiation causes damage to tissue, and the sources of this radiation even though low-level, cannot be turned off. Direct exposure can be avoided by suitable shielding and proper handling of the sources.

Ingestion or contamination is less likely to occur but the consequences are far more disastrous because the radioactive material may stay in the body, concentrating in a specific organ. It can irradiate tissues for a long period of time. This hazard can be kept negligible by hermetically sealing the sources against leakage and by proper handling.

Shielding and leak testing

Shielding against beta radiation is very simple because the highest-energy beta particles are stopped in less than one centimeter of aluminum. Normally, the heavy walls surrounding the source and ionization chambers absorb all beta particles and though the absorption results in some secondary x-ray radiation, this, too, can be stopped by supplementary lead shielding.

Shielding against gamma radiation involves lead sheets and sometimes concrete walls around the equipment to reduce the radiation to a safe level. Since intensity falls off as the square of the distance from the source, distance itself is a most useful shield. Conspicuous warning signs should be placed around the apparatus to keep operating personnel far enough away to be in a region of low intensity. Only personnel trained in the proper handling of the equipment and the sources should be permitted to service or otherwise approach the instruments.

The AEC requires that all sealed sources be checked for leaks at least every six months. In its simplest form this check consists of wiping accessible outer surfaces of the source and surrounding parts with a moistened cotton swab to pick up any leaked material, and studying the wipings with a sensitive Geiger counter. This test can normally be done without interrupting analyzer operation, although it is desirable (at less frequent intervals) to remove the source and check its entire active surface. Again, these tests must be performed by a person familiar with the hazards and proper procedures. Some suppliers and organizations in the radioisotope field supply this service to users who do not have their own testing facilities or personnel.

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The author thanks the editors of "Analytical Chemistry" for permission to use Table 2, which appeared originally in Reference 4; and thanks the ISA for permission to use Tables 3 and 4 and Figures 2 and 3, which appeared originally in Reference 3.

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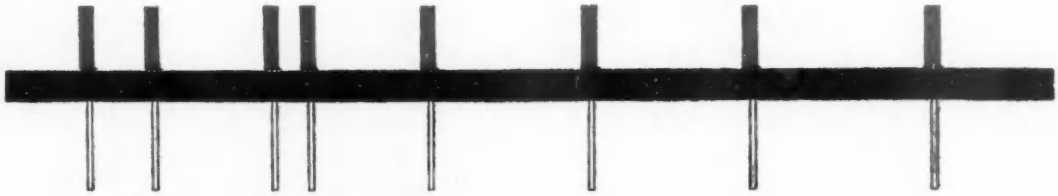

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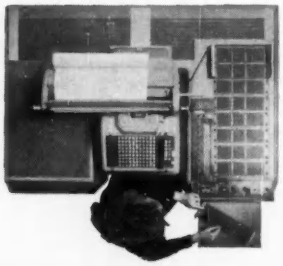

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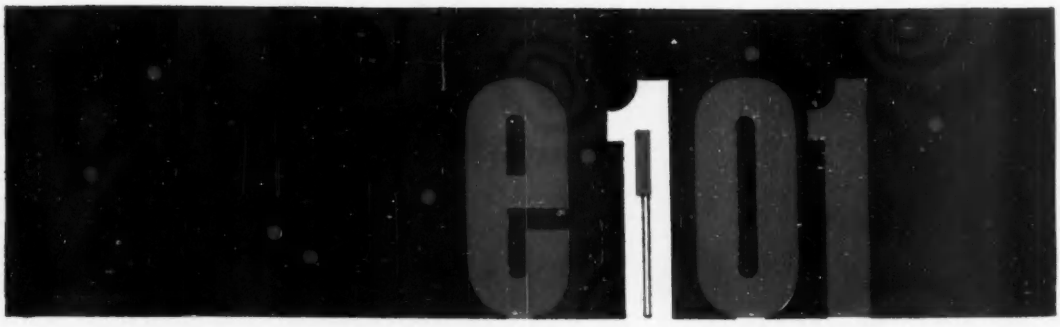

The Digital Answer to Data Telemetering

Telemetering means, literally, measuring at a distance. Broadly, it includes all the various systems and techniques of data transmission applicable to remote indication and control of measurable parameters. The analog methods, including pulse-amplitude, pulse-width, and pulse-count systems, are often too susceptible to loss of information in transmission, especially in wide-band (high-information-rate) applications. Digital systems based on binary code techniques offer maximum accuracy and versatility plus the most efficient use of the time-bandwidth factor, to which costs can be related. The characteristics and requirements of digital data transmission systems are discussed in this article from the vantage-point of long experience.

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The transmission of quantitative data has become an important part of industrial processes. The following conditions contain some of the factors which contribute to the need for transmitting measurements (telemetering) for remote observation and control:

- When the data source is inaccessible or untenable for a human observer, e.g., rockets and missiles; radioactive or otherwise dangerous areas; geographically remote observation posts, etc.
- When the use of a human observer at the data source is too costly, e.g., when monitoring of electric utility distribution points, substations, etc., is only occasional.
- When speed and accuracy demands on the data exceed the capabilities of a human observer.
- When data are required from many sources for rapid processing at a central point.

Basic transmission methods

The two basic forms of data representation are analog and digital. The common analog form makes use of physical or electrical variations which resemble the observed data. Thus, an analog system is defined as one in which some attribute, such as amplitude, frequency, pulse count, pulse position, pulse duration, etc., is proportional to, or a function of, some desired measurable parameter. The digital form uses abstract codes having some arbitrary but logical relationship to the observed data; a system based on this code is defined as one in which discrete electrical or mechanical symbols are used in rational combinations such that the number of discernible levels is considerably greater that the number of symbols used.

Figure 1 is a diagrammatic comparison of various methods of representing data for transmission. Although not generally regarded as such, all modulated class "C" amplifiers are pulse amplitude devices and can be arranged to represent data in the familiar scheme shown in Figure 1A. The pulses in any system are never square-cornered rectangles after transmission through a system, and distortions far in excess of those shown are frequently present. The effect of random noise variations is not shown in Figure 1, but it is easily appreciated how superimposed noise increases the uncertainty with which a system can reconstitute the peak level of the pulse amplitude samples. Likewise, noise superimposed on pulse time signals (Figure 1B) makes it more difficult to tell at which point the pulses begin and end. There has

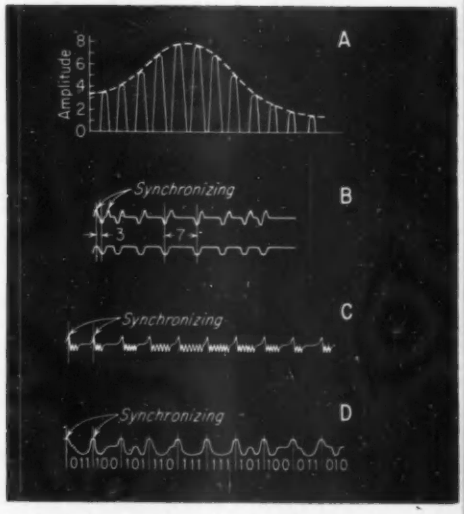

FIG. 1. A comparison of various data representation schemes. The polarity-sensitive synchronizing system is shown for simplicity.

A. Pulse amplitude modulation. The envelope of the pulse amplitudes closely approximates the original signal.

B. Pulse position, pulse time, and pulse width modulation. Analog schemes closely related to both phase and frequency modulation.

C. Pulse count system. Framed by sync signals, separate pulses are used for each discernible level of sampled signal. Wastes time and bandwidth.

D. Pulse code modulation (digital). Separate code combinations represent each level of sampled signal. Uses time-bandwidth very efficiently.

been some confusion regarding the nature of pulse count systems. Many of the pulse count systems have been referred to as digital, presumably because of the use of "binary" pulses and digital-counter-type readout. The behavior of these systems in the presence of noise, and their time-bandwidth utilization characteristics, stamp them clearly as analog systems. It can be seen intuitively from Figure 1C that noise pulses into the system will be counted as increments of level, thus introducing errors. The number of incremental errors will increase in direct proportion to the noise in the system.

Digital signals, as shown in Figure 1D, are almost invulnerable to noise below a certain threshold and trade bandwidth for signal-to-noise ratio and/or increased resolution in a very efficient manner. If, for example, the pulse-count system were to be designed for a resolution of one part in 1,000, then time and bandwidth must be provided for up to 1,000 pulses in each frame. The binary digital system illustrated in 1D, however, can accomplish this same increase in resolution by expanding from the present three pulses ($2^3 = 8$) to ten pulses per frame ($2^{10} = 1{,}024$).

Although digital-data transmission by electrical means (telegraph with Morse code, etc.) is an older technique than analog-data transmission, only in recent years has the transmission of measurement and control data by digital means become widespread.

Certain advantages result from the use of digital rather than analog methods of data transmission. These advantages are:

- high transmission accuracy in the presence of high noise levels and other forms of interference, which tend to reduce the transmission accuracy of analog signals.
- a more efficient use of the time-bandwidth product, or conversely, better interference rejection (signal-to-noise ratio) for the same time-bandwidth product.
- greater adaptability for simple remote control without the need for high-gain servo amplifiers, etc.
- high resolution (e.g., one part in 1,000 and better) with comparative ease—by contrast, one percent system drift in conventional analog systems, affording a resolution of no better than one part in 100, is not unusual; to do significantly better generally requires elaborate analog equipment.

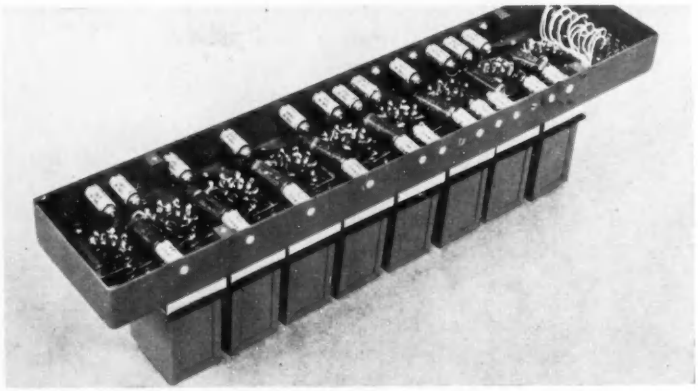

FIG. 2. A digital potentiometer in which decoding relays select various values of resistance, connect them in a circuit that simulates a ring potentiometer.

An additional obvious advantage accrues when digital data transmission techniques are used in connection with digital input and/or output equipment such as digital computers.

Basic digital data system

The basic elements in a simple digital-data transmission system may include the following:

1. Data source—such as measurement transducer switch position.
2. Encoder (analog-to-digital converter)—a means for converting from the input element to a digital code form.
3. Transmitter—the assembly which samples the code present, codes it, and places it upon or into the transmitting medium.
4. Transmission medium—such as wire line, radio link, etc.
5. Receiver (also may be called a distributor)—a device for accepting the digital data from the transmission medium and distributing it to the proper point in the decoder.
6. Decoder—a relay network or other device which accepts the distributed data from the receiver and has outputs connected to the readout device.
7. Readout device—may be a visual indicator such as lighted windows, an automatic typewriter, etc.

In assembling the digital-data transmission system, it is generally best to digitize as close to the data source as possible. Prior to the digital conversion, the data is more susceptible to error. The digital-data transmission system should have the greatest degree of compatibility with the intended input and output devices. This is why, in some impressive recent work, existing familiar devices such as Bourdon pressure gages, float-type level gages, and resistance bulbs for temperature measurement have been used as primary sensors in digital systems. The adaptation of these standard devices has, in general, imposed severe requirements upon designers and these have been met admirably. There are clearly some fields in which existing instrumentation or input devices are incompatible with digital techniques. It is in this latter case that new designs are required to prevent an overly complex digital conversion requirement.

Factors governing the choice of a system

The design of a digital-data transmission system is generally determined by methodical consideration of six factors. These are output form, number of inputs and/or outputs, accuracy, data rates, cost, and size. Selection of the particular code to be used is an important consideration in itself.

Ultimate use of data frequently dictates the desired output form of a given system. Output forms include visual indicators, recording devices, storage units, or electrical forms suitable for direct use by computers or for control purposes.

Output forms. The most popular form of visual readout is the decimal indicator, whose principal advantage is error-free readability. In this same general class are lamp-matrix indicator systems. Permanent recording of digital data is done by various printers and electric typewriters.

In binary-coded-decimal digital systems, data is transmitted in groups of four binary digits (serial or parallel). The decoder simply operates upon one decimal digit at a time, and, particularly where operating to printers and punch devices, no intermediate storage of data is needed. An example is the Bendix micrometeorological telemetering installation at Dugway, Utah[8]. In this system, information is

A SHORT HISTORY OF DATA TRANSMISSION

The simplest approach to electrical transmission of measurement data is to derive an electrical signal from some part of an indicating or control circuit and transmit it in a form resembling the original signal. At the receiver, the original signal is reproduced and used to operate the indicator or controller involved. This is analog transmission. Most short-distance (in-plant) and many long-distance data transmission systems still use this relatively simple method.

As transmission distances became greater and data requirements more complex, two basic limiting factors appeared. One of these is related to characteristics of the transmission medium, such as noise in the system, nonlinear distortion, phase and time delay distortion, and frequency distortion. The other is related to factors influencing the cost of the system, such as precision, reliability, bandwidth, and data-transmission rates.

For many years the communications engineer had only a vague feeling for the relationships between: 1) the information being transmitted, 2) the time required for transmission, 3) the bandwidth available, and 4) the relative strengths of the signal and the random electrical fluctuations (noise). Experience indicated a direct relationship between the maximum signaling rate and the bandwidth in a given transmission circuit. A telephone circuit, for example, required greater bandwidth than a telegraph circuit. Attempting to force too much information over a circuit degraded the signal.

By experiment and experience the communications engineer acquired an intuition and a wealth of empirical data which served him well for many years. In 1928, R. V. L. Hartley presented a paper[1] which explored the bandwidth limitation of signaling rate from the standpoint of stored energy in the system and devised a quantitative measure of information, but the inferences were not widely recognized. With the coming of radio and the vacuum-tube amplifier, transmission of information over greater distances became feasible. It then was apparent that bandwidth was not the only limitation. A message which became mixed during transmission with sizable amounts of random noise contained less information when received than when transmitted.

In the early 1940's this situation was still regarded largely from an empirical point of view. The useful information-transmission capacity of a circuit was known to decrease with decreasing bandwidth or signal-to-noise ratio. The invention at this time of the wide-band fm system by E. H. Armstrong opened up new avenues of thought. Here was a system in which the signal-to-noise ratio could be improved by increasing the bandwidth beyond that "theoretically" required to transmit the information. The question of whether this "trading" of bandwidth for signal-to-noise ratio was a general property of communication circuits was not fully answered until after World War II, when it was found that pulse code modulation (digital) could accomplish the "trade" even more efficiently than wide-band fm.

An important contribution to the understanding of the underlying principles of information transmission was made, however, during the war. While working on the development of predictors for anti-aircraft weapons, Norbert Wiener of MIT was led to the realization that all communication problems are fundamentally statistical in nature. To transmit any new and useful information, a signal must be a time function that is not precisely predictable. What can be generally known about the signal is its statistical character. Thus both the signal and the noise can be described in statistical terms. Building on the work of his predecessors, C. E. Shannon presented a complete "Mathematical Theory of Communication" in 1949[2]. It is on this foundation that modern information theory stands.

Although an exposition of information theory concepts is beyond the scope of this article, it is worthwhile to note some of the important new ideas involved.

The contribution of the new theory

The communications engineer in the '20's and '30's, operating primarily on raw intuition, generally regarded his continuous analog system as being "theoretically" capable of representing an infinite number of messages. He recognized certain theoretical limitations which he generally regarded as being limitations of the equipment and not necessarily of the method.

Today he has an excellent mathematical model against which to measure the performance of his system. He knows that the message-handling capacity of the "continuous" system is limited to a finite and theoretically determinable number of discrete messages. He realizes that any band-limited signal of finite duration can be completely described by a finite number of discrete amplitude samples. The minimum number of samples required is twice the time-bandwidth product. He also realizes that, almost always, his continuous analog transmission system is less efficient from the standpoint of utilization of information capacity or time-bandwidth product than a properly designed digital system.

It can be shown from the standpoint of coding for maximum efficiency that the symbols used for messages sent should be assigned so that they are equally likely. Determination then becomes a series of choices between one of two (binary) conditions. This concept leads to the binary digit (bit) as the basic measure of information. Binary-coded digital-data-handling systems are now becoming widely used.

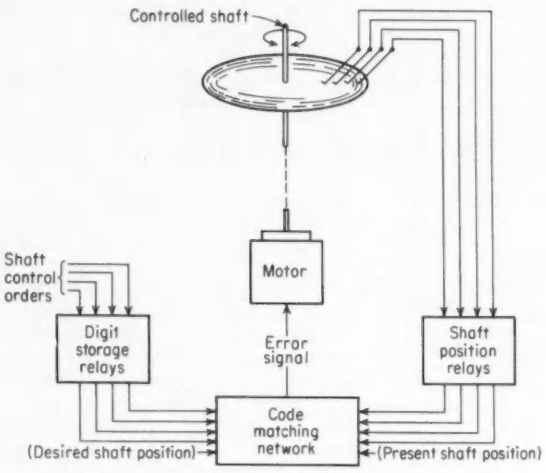

FIG. 3. A digital code-matching shaft positioner.

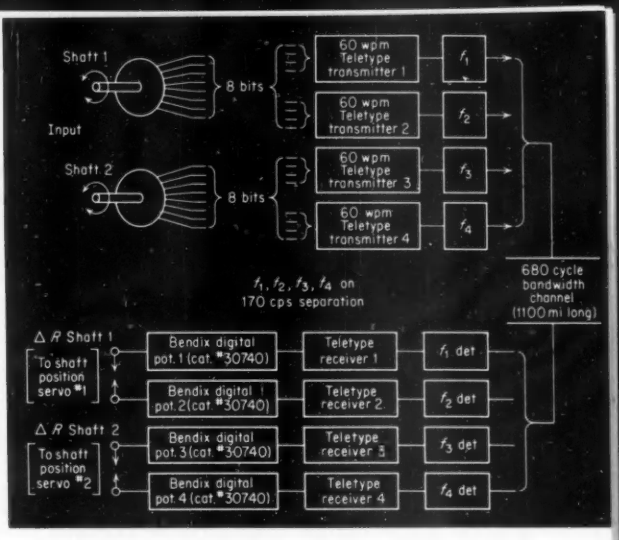

FIG. 4. An example of series-parallel digital-data transmission as used in a system now in operation.

programmed in sequences of decimal digits and transmitted as the presence or absence of groups of four discrete audio tones over a telephone pair (plus a fifth "guard" tone). The receiver decoder accepts each four-tone code in sequence, deciphers these codes, and then operates an electric typewriter and card-punch. Lamp-matrix indicators can operate directly from any code of binary notation, including complex reflected-binary-reflected-decimal codes.

When coding to a binary-coded-decimal form, ten of the 16 possible codes must be chosen; proper selection can minimize the number of contacts needed on the decoding relays. Permanent and semi-permanent storage of digital information may be provided by the punched-card, perforated-tape, magnetic-tape, or magnetic-drum techniques.

Digital information can be transmitted directly to a digital computer rapidly and accurately. But where dial or position indication is desired, digital-to-analog conversion becomes necessary. Process trends, for example, may be studied more readily from a graphic record than a tabular record. The analog form may be a varying voltage for input to analog computers. A digital potentiometer, which accepts digital data and converts this to an analog voltage, is shown in Figure 2. Thus, digital-data transmission techniques can lend accuracy and reliability to either digital or analog computers working in real-time systems.

Digital data may also be converted to input signals to servo loops for direct control of valves, actuators, and controlled devices. A code-matching digital remote shaft-positioning device appears in Figure 3.

Number of channels. Another factor which helps govern the type of digital-data transmission system selected is the number of data sources and information channels available. If there are many measurement transducers or other types of inputs to a given system and the number of transmission channels is limited, multiplexing information over one or more of the channels may be the answer.

Several serial systems may be multiplexed in a given audio circuit by operating each serial system at a discrete audio frequency. Digital-data-transmission systems lend themselves particularly well to time, frequency, or circuit multiplexing techniques. One system using both time and frequency multiplexing is shown in Figure 4.

Accuracy. High accuracy and repeatability frequently dictate the choice of a digital system. Limited accuracy can be provided by time-shared encoder systems, which though simple, can serve as a base for future expansion to high-accuracy systems. High accuracy and good repeatability can often be provided only by digital techniques. The selection of codes depends more often on the decoding circuitry or on the requirements for self-checking than on the level of efficiency needed. The system shown in Figure 4 is an example of this thinking.

Transmission rate. If information is to be transmitted upon demand only, the type of transmission employed (serial or parallel) becomes a very simplified function of the bandwidth available versus maximum sampling rate. If the transmission is to be at random intervals, the system becomes somewhat more complex and the probability of quantities of information needing transmission in a given time interval must be determined. Continuous data transmission must be defined. For example, in many industrial applications "continuous telemetering" includes data samplings from a given measurement transducer at intervals of 15 sec. Therefore, the requirement of sampling frequency must be known in determining the rates of transmission necessary for so-called continuous data transmission.

Data storage. One way to increase data-transmission efficiency is to store the data either before transmission or before presentation to "fill the voids" in the use of the data link. Sampling a number of variables at a given instant does this. All variables may be sampled by demand order, stored, and then transmitted in sequence, thereby diminishing bandwidth requirements and increasing the transmission efficiency. The following example will illustrate the difference in systems.

Required: 20 eight-digit measurements, at a maximum reading rate of all 20 every 5 min.

Solution 1: All 20 measurements transmitted simultaneously upon readout order. Bandwidth required, on presumed 200-cycle spacing per digit, is 8 x 20 x 200 = 32 Kc. Time required for transmission, 100 millisec. No storage of data required at origination or digitizing point.

Solution 2: All 20 measurements sampled and digitized simultaneously, all 20 digitized measurements temporarily stored at origin. Serial transmitter gives start and sync signals, then transmits the 20 eight-digit codes as pulse code data, with appropriate sync signals, at the rate of 15 pulses per sec. Time required for transmission = 8 × 20 + 20

(start, stop, and sync pulses) ÷ 15 pulses per sec = 12 sec (approximate). Bandwidth required, 45 cps.

Solution 1 requires considerable bandwidth and tone equipment and no storage, and permits future expansion to a 1,600-bit-per-sec information rate, or to 600 samples per minute of all 20 measurements without additional bandwidth or equipment. The 32 Kc. bandwidth could be provided by seven audio "talking grade" circuits, with a representative total cost of seven circuits × $4.75 per mile per month = $33.25 per mile per month.

Solution 2 requires limited bandwidth and data storage (such as relays), and provides for additional future expansion to a 13.3-useful-bits-per-sec rate, or to five samples per minute of all 20 variables. The 15-pulse-per-second bandwidth can be provided by a simplex telegraph grade circuit, with a representative cost of 75 cents per mile per month.

Cost. The cost of a digital-data-transmission system is, in general, a function of the speed of data transmission employed. A slow-speed data transmission system uses many electromechanical components (such as those used in the telegraph and Teletype operations). These components are extremely reliable, are manufactured in large quantities, and generally are low in cost. As the rates of data transmission increase, equipment costs may increase sharply. Contributing to these higher costs are high-speed relays and electronic, magnetic, and semiconductor devices used in sampling, commutation, and transmission. The cost of the transmission medium is also, in general, a function of bandwidth. One of the lowest-cost circuits is the so-called telegraph-grade circuit. A voice or talking-grade telephone circuit may rent for as much as six times the cost of a telegraph circuit. Though running private wire lines may not necessarily indicate this great cost difference, there is a threshold, particularly in the use of privately owned microwave, at which considerable bandwidth is available at a fairly constant nominal cost figure. Obviously, the cost of the transmission medium must be calculated not on a per-mile basis, but on a total circuit basis in order to derive a fair comparison between several techniques. Actually, the cost per message on a high-speed system used at full capacity is frequently lower than that of a low-speed system.

Size and weight. The size and weight of equipment for digital-data-transmission systems varies considerably. Typical industrial equipment, which features low initial cost, is often quite bulky and inefficient, Figure 5. But many industrial applications remove any incentive to diminish the size of this equipment by providing more than enough space. Digital-data-transmission equipment is also available for airborne applications, and consists here of modules exhibiting outstanding strength and weight efficiencies and reflecting the latest semiconductor techniques. Commercial digital-data-transmission equipment, by its very competitive nature, must be, in the word of the trade, "sledge-hammer proof", i.e., must meet such requirements for hazardous areas.

Digital code forms

Digital data transmission systems thus far have employed two basic forms of binary data representation: 1) sequential pulse code, and 2) frequency code or pulse-frequency code.

Sequential pulse code is, in general, a time-divided sequence of pulses which are essentially binary in character. Thus the receiver has only to discriminate between the presence or absence of pulses, in the case of amplitude pulses, or between one frequency and another, in the case of frequency shift keying, see Figures 6A and B. It is much easier, in case of noise, to distinguish between two widely separated conditions than between closely spaced levels, as must be done in analog systems.

There is a serious disadvantage, however, in sequential pulse code circuits. The transmitter and the receiver must be closely synchronized in order to prevent errors due to confusion of pulse sequence. In conventional systems this synchronization, is, of necessity, analog. Thus the synchronizing system is subject to noise and other forms of distortion in the same way that a pulse position or pulse time analog system is. Synchronizing is therefore frequently the limiting factor in such a system. Furthermore, the transmission of synchronizing information requires additional bandwidth. This situation becomes most troublesome when the data is time-divided, particularly by random programming.

Pulse-frequency codes, Figure 6C, generally can be arranged to circumvent the synchronizing problem by sending a complete datum word as an array of simultaneous tones, each representing a binary digit. Here, however, the selective fading conditions frequently encountered on h-f radio circuits, and large amounts of distortion due to nonlinearity of the transfer characteristics give rise to serious difficulties. The latter may be the result of generation of spurious harmonic and intermodulation frequencies. These spurious frequencies are completely predictable, however, so that with proper system design a considerable amount of nonlinear distortion can be tolerated.

Several binary codes have been developed and are used both in pulse-code and frequency-code systems. Probably the most widely known code for representing numerical data is the arithmetic or "natural" binary code, in which each binary digit represents a power of 2 just as in our conventional decimal code each digit represents a power of 10. A four-digit arithmetic binary code is shown in Figure 7, along with the corresponding decimal numbers.

An interesting problem arises in connection with the use of this code

FIG. 5. Frequency code terminal equipment, showing simple low-cost packaging.

with practical encoding devices, such as digital shaft encoders. Such devices are subject to vagaries of mechanical assembly, and if slightly misaligned can cause gross coding errors at the boundaries between increments. Imagine that the code shown in Figure 7B is placed on an etched circuit shaft encoding disc to be read by contact brushes. At the boundary between number 7 (0111) and 8 (1000), for example, a slight misalignment of brushes could result in a readout of 15 (1111) or zero (0000).

Several solutions exist for this problem. One, rather widely applied, is to use a mechanical "Geneva" mechanism or its electrical switching circuit equivalent, so arranged that no readout can occur near the quantum boundaries. Another is to arrange the codes of the "natural" binary in a completely different sequence, Figure 7C, known variously as "Gray code",

"reflected binary", or "cyclic binary". This code has the unique property of changing only one digit at each quantum boundary, and thus allows no gross coding errors due to misalignments. The dotted lines in Figure 7C show how the code is derived. Each time a digit of higher significance changes from 0 to 1 the entire sequence above the dotted line is reflected below the line as if in a mirror. The cyclic character of the code is shown in the squares under each digit. If one reads from left to right, evaluating alternate 1's as plus and minus, the code can be interpreted as a number (e.g., the number 10 or 1111 is evaluated as plus 15 minus 7 plus 3 minus 1, the number 12 or 1010 as plus 15 minus 3).

The great variety of coding arrangements in use results from the ingenuity of the system designers, and one sometimes feels that there are as many codes as there are types of systems. Telegraph and Teletype codes have been in use for a number of years and are widely known. So are pulse-count-decimal, as used in telephone dialing, and biquinary code, widely used in telephone practice. The latter is a decimal array of combinations using one binary (two-level) digit and one quinary (five-level) digit.

A group of codes widely used in connection with computers and data-logging systems is generally known as binary-coded-decimal. In these codes each decimal digit is represented by four binary digits. Since there are 16 possible combinations and only ten are used, many varieties of binary-coded-decimal notation exist. The most common is the arithmetic, wherein the binary notation has the conventional power of two or 8-4-2-1 connotation. Each group of four binary digits is used from 0(0000) to 9(1001) and is then treated as a conventional decimal digit with powers of ten.

Probably the next most widely used code of this type is a reflected code, where the principle of code reflection shown in Figure 7C is extended to the decimal notation as well (e.g., 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 20, etc.). Note that this results in a change in only one decimal digit at a time. Since reflected binary codes are used within the decimal notation, this means that a complete minimum error configuration is preserved. All reflected codes are easily translated to their conventional equivalents by scanning from the most significant toward the least significant digits and following these rules:

1. Translate first digit as written;
2. Translate the remaining digits as written if the next more significant digit translates to an even number;
3. Translate the remaining digits as their inverse (i.e., 9 to 0, 8 to 1, etc.) if the next more significant digit translates to an odd number.

These rules also apply in translation of reflected binary codes, except, of course, that the inverse of 1 is 0 and of 0 is 1.

Code selection

The most efficient code for a specific input/transmission/output problem is often available, and its selection can often lead to great advantages and economies. Reference 5 shows the importance of code selection in a code-matching remote shaft positioning device. By proper code selection and arrangement, several requirements were met, including minimum error and a directional sense to the matching of the input-output codes.

In one application, the shaft position was to be sent in a random program with other data over a radio link using narrow-band fm. The actual transmission was done by means of a burst of frequency-coded address information using nine tones—no more than five at one time—followed by a burst of quantative information using the same tones—no more than five at a time. The address code determined which control device actually registered the information. The restriction in the number of tones was to mini-

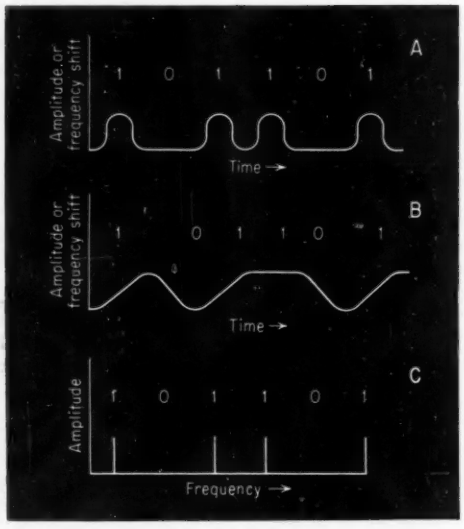

FIG. 6. Forms of digital-data transmission.
A. The number 45 represented in natural binary, pulse code, return-to-zero transmission.
B. The number 45 represented in natural binary, pulse code, non-return-to-zero transmission. This type of representation makes better use of bandwidth at the expense of more difficult synchronizing.
C. The number 45 represented in natural binary pulse frequency code. The spectrum shown is transmitted as a burst or chord of frequencies.

A-Decimal	B-Natural binary	C-Reflected binary
0 0	0 0 0 0	0 0 0 0
0 1	0 0 0 1	0 0 0 1
0 2	0 0 1 0	0 0 1 1
0 3	0 0 1 1	0 0 1 0
0 4	0 1 0 0	0 1 1 0
0 5	0 1 0 1	0 1 1 1
0 6	0 1 1 0	0 1 0 1
0 7	0 1 1 1	0 1 0 0
0 8	1 0 0 0	1 1 0 0
0 9	1 0 0 1	1 1 0 1
1 0	1 0 1 0	1 1 1 1
1 1	1 0 1 1	1 1 1 0
1 2	1 1 0 0	1 0 1 0
1 3	1 1 0 1	1 0 1 1
1 4	1 1 1 0	1 0 0 1
1 5	1 1 1 1	1 0 0 0
10^1 10^0	2^3 2^2 2^1 2^0	±15 ±7 ±3 ±1

FIG. 7. Common binary codes, as compared to decimal.

mize intermodulation problems in the voice-grade radio link.

The code required for the various shaft positioners then had to meet not only the specifications listed above, but also had to be 1) completely symmetrical so that the shaft would always proceed in the shorter direction to the ordered position, and 2) contain no more than five "on" digits in any number. A code containing 180 numbers (2-deg spacing) was worked out which met all these conditions and still preserved the minimum error characteristic of the code. This was accomplished by removing all numbers with six or more "on" digits, as well as an adjacent code and the two codes diametrically opposite to these.

When all the undesired codes were removed, the code so obtained was no longer "cyclic" or "reflected" binary, but did have "minimum error" and complete loop symmetry.

A digital-to-analog converter which accepts incoming digital data, yet performs as a synchro transmitter, can be realized through unique code selection. The code used by this digital synchro, Figure 8, is a minimum error code which permits input from an electromechanical transducer for decoding by relays that generate a signal for the operation of a standard synchro receiver.

In the same general category as code selection come self-checking codes and fail-safe features. The general characteristic of self-checking codes is "redundancy". This is illustrated in the common parity check, which is based on the fact that the probability of two errors being generated in one word is the square of the probability of a single error. The receiver is arranged to recognize only codes containing, say, an even number of 1 digits (this can also be done for odd numbers), and these recognized codes are then used in conventional fashion, except for the addition of one extra binary digit known as a parity bit. If the number of 1 digits in the regular code is even, then the parity bit is 0, but if the number of 1's is odd the parity bit is 1, thus making all valid codes contain an even number of 1's. If the received code contains an odd number of 1's, the system either disregards the message or attracts the attention of a human operator. This philosophy is frequently extended to the point where sufficient redundancy exists to allow not only for detection but also for correction of the errors.

Trends in digital transmission

Much has been made recently of the digital computer as a data-transmission element. One popular concept is that which pictures the computer automatically accepting data from several separated and/or independent sources, processing the data, and then delivering optimum output control signals for continuous process control. This philosophy is being applied also to pipeline dispatching and to air-traffic control. The digital computer with its tremendous capacity, reliability, and insensibility to drift appears to be an ideal tool for optimizing various industrial processes and operations. It seems logical that data being delivered to a digital computer should be derived from a digital transducer output at the measurement point, thereby gaining the benefits of digital data transmission for the complete system. It is interesting to note that there already exist virtually all the elements necessary to permit a digital computer working in real time to operate as part of a transmission system.

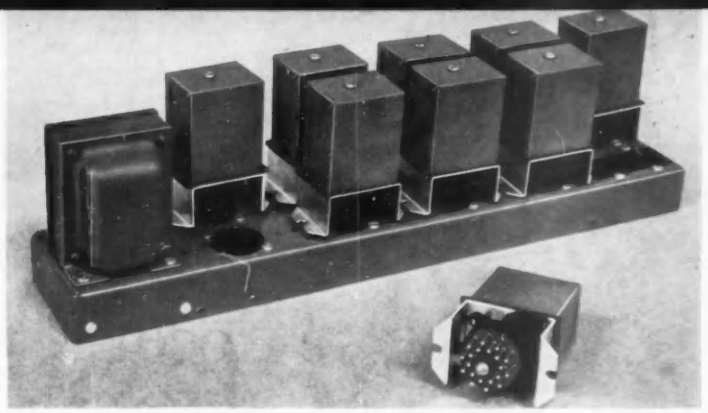

FIG. 8. A digital synchro. Decoding relays select various voltage windings from multiple winding transformer, connect them in proper relationship to simulate synchro transmitter output.

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E. A. Ragland (left) and D. E. Wassal (right) got their BS's in EE from midwestern universities 10 years apart. Ragland's came in 1939 from Kansas State College, and right afterward he went to work for General Electric Supply Corp. Posts with Stone & Webster and Brush Development followed, and in 1952 he joined the Data Transmission Dept. of Bendix Aviation's Pacific Div. He was made chief in 1956. Wassal, who graduated from Washington University in St. Louis in 1949, did work for Petrolite Corp. before coming to Bendix in 1954. Today he heads application engineering in the Data Transmission Dept.

Correlation Analysis of Tape-Recorded Data

Except for one analog method[5], correlation functions of recorded data have been generated either by a general-purpose digital computer or by slow and tedious manual routines. The special magnetic tape scanner described here permits generating the correlation functions automatically in a few minutes. It uses rotating heads to read a stationary section of tape selected from its reels for analysis.

GEORGE FENIMORE
The Ramo-Wooldridge Corp.

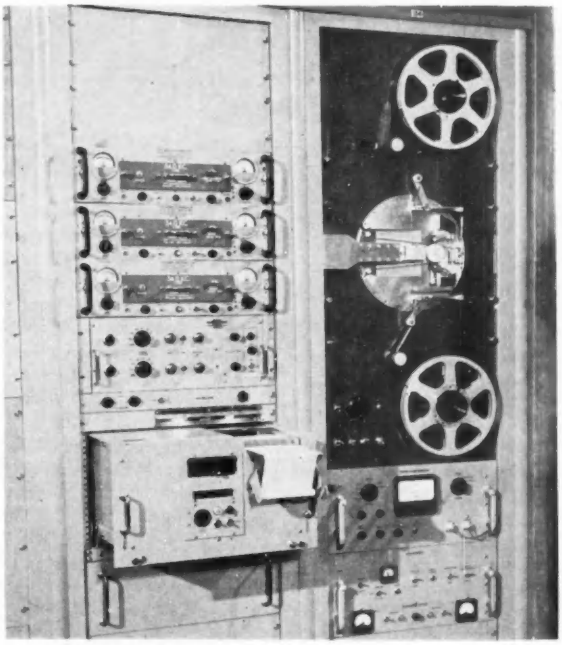

FIG. 1. Correlation function computer mounts special Magnescanner at right, fm discriminators and computer at left above output recorder.

To properly apply automatic control, the control engineer must know the frequency response characteristics of his system. These characteristics are not easily calculated for complex systems, and usually have to be determined experimentally. Unfortunately, many large physical systems cannot be disturbed by the usual methods, which require the use of significantly-large step, impulse, or sinusoidal inputs. Costly amounts of off-quality product may result, or the system may be seriously damaged. The alternative is to determine the system's frequency response from its normal behavior.

The most powerful technique so far developed for finding the frequency response of such systems makes use of the auto- and cross-correlation functions of normal random variations in the system. A thorough mathematical exposition of this technique was made by J. B. Reswick of MIT[1] in CONTROL ENGINEERING for June 1955[1]. Briefly, the cross-correlation function of two random variables can be developed by shifting one of two simultaneously recorded waveforms by a small amount, and taking the average value of the products of all the ordinates to get one point on the correlation function. The function waveforms are then shifted again by a small amount and the new products of the ordinates averaged to get the second point on the correlation function. This must be done for a statistically adequate number of shifts. The correlation function developed by comparing a random function to itself is called its auto-correlation function.

This technique is important in control systems work because it has been proved that the cross-correlation of the input and output of a randomly varying system is related to the auto-correlation of the input by the system's response to a unit impulse. Thus, it is necessary only to record simultaneously the normal random variations at the system's input and output, and then to average the products of their waveforms for a sufficient number of shifts, as outlined above. Several methods exist[2, 3, 4] for finding the frequency response of a system from the impulse response so obtained. An automatic computer has been described that will generate the correlation functions of random variables recorded on paper strip charts[5].

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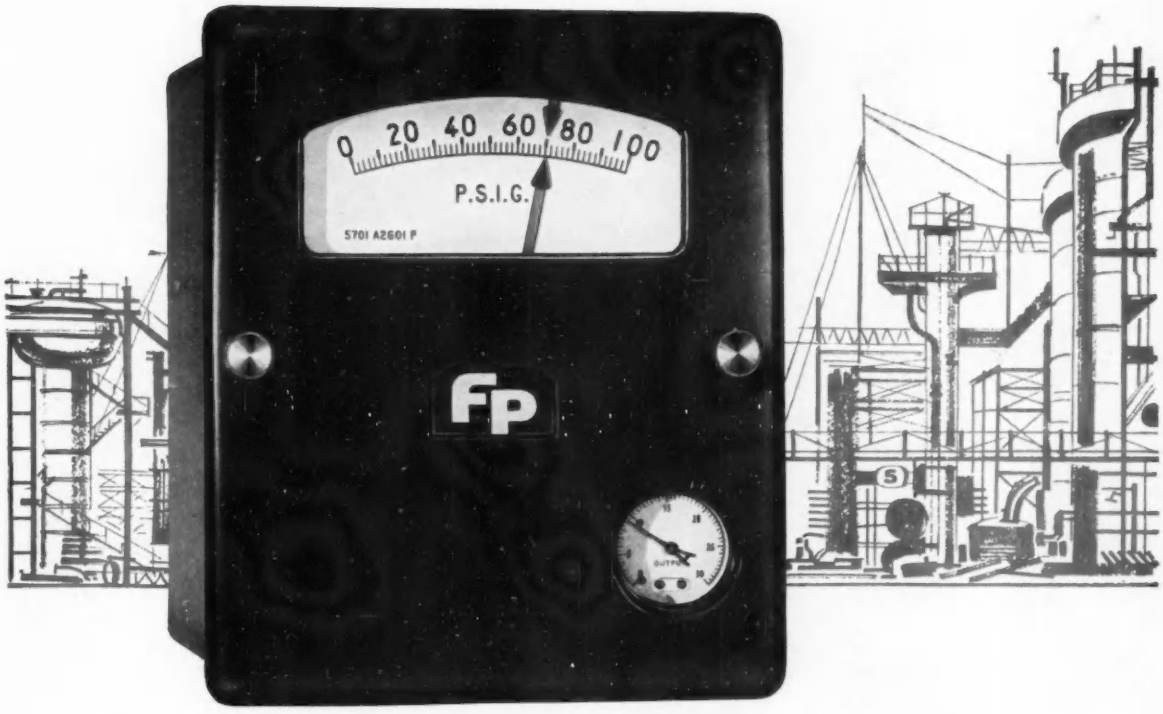

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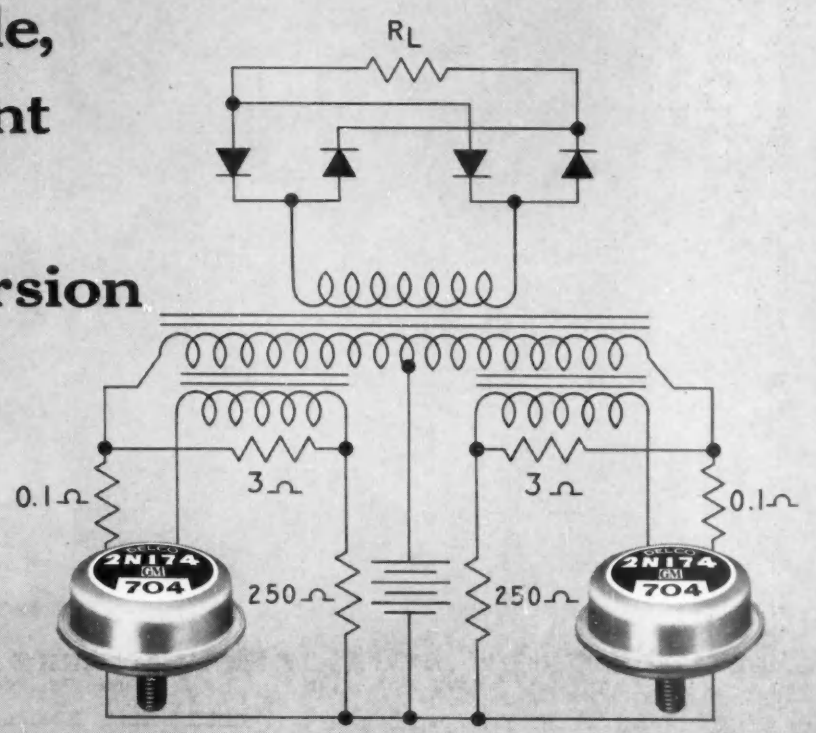

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Maximum collector voltage	60	80
Saturation voltage (12 amp.)	0.7	0.7
Power gain (Class A, 10 watts)	38	38
Alpha cutoff frequency	0.4	0.4
Power dissipation	55	55
Thermal gradient from junction to mounting base	1.2°	1.2°
Distortion (Class A, 10 watts)	5%	5%

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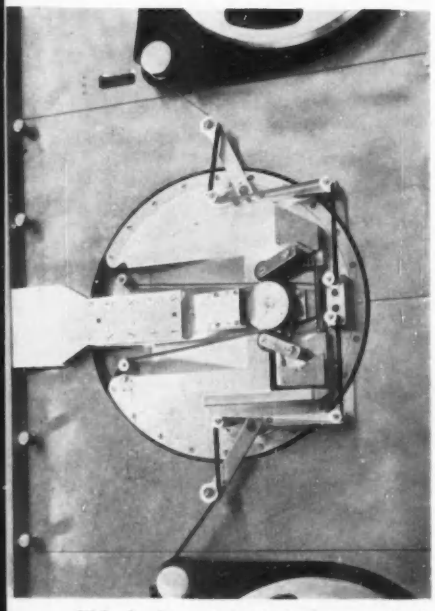

FIG. 2. Concentric playback arm on back of this panel rotates around outside of drum to read 28-in. section of tape selected from reels. Tape is held stationary and read by two heads that are displaced a little each revolution.

cently installed a correlation function computer in the vibration analysis section of its new Data Reduction Center at Los Angeles. This computer analyzes data recorded on magnetic tape by means of a special adaptation of a tape scanning and handling mechanism built by Ramo-Wooldridge and called the "Magnescanner". The computer is pictured in Figure 1, with the Magnescanner at the upper right.

The Magnescanner, seen close up in Figure 2, loops a section of the recorded tape around a stationary drum. This section of tape then is held fixed on the drum and is read by magnetic pickup heads that rotate around the periphery of the drum on a concentric arm. Peripheral speed of the heads is 90 in./sec for this application. The tape-handling system can move the tape forward or backward while the playback arm is operating, so that the data can be searched for significant portions.

The arm that carries the heads can be seen in the rear view of the Magnescanner, Figure 3. Note that the playback head preamplifiers are mounted on the rotating arm to boost the signal before it is brought out through the sliprings. Two data channel heads are mounted on separate, concentric arms linked by a cam mechanism. The cam advances one head relative to the other in 47 exponential steps from zero displacement to a total of 2.5 in. The head moves forward automatically at the start of each revolution as the arm passes a short gap in the drum surface. After a 29-in. section of the tape has been scanned through the complete sequence of displacement steps, a new section is automatically moved onto the drum and the reading heads are re-indexed at zero to begin a new cycle.

A third head (mounted beside one of the data heads) reads a frequency reference signal channel recorded with the data. As many as seven pickup heads could be mounted on a single arm to read ½-in. tape. For precision reading of taped data, the playback heads must be in contact with the tape but must not exert damaging pressure. The drum of the Magnescanner is coated with a resilient surface material of precision dimensions that keeps the tape and heads in contact with almost no pressure, and has sufficient elasticity to permit the heads to ride over specks of dust or slight variations in tape thickness.

Signals from the sliprings are preamplified and sent to the computing and recording system where the fm carrier signal from the tape is demodulated, the two signals multiplied together, and the resultant product integrated. At the end of each rotation of the arm, the integral, which is one point on the correlation function, is recorded and the integrator reset.

The Magnescanner can be used with suitable display equipment to allow a quick look at recorded information or to scan volumes of data for significant sections at high or low speeds. In the latter case, it provides precision output for detailed analysis. Some other Magnescanner applications: determination of time of an event; determination of deviation limits of telemetering; display of information on large screens; component of wave analyzers; display of transient phenomena for detailed study; and oscilloscope display for photographing.

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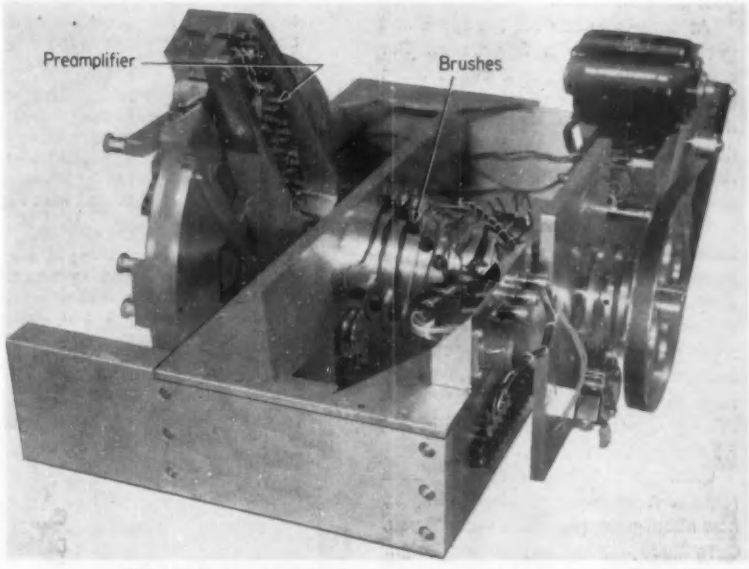
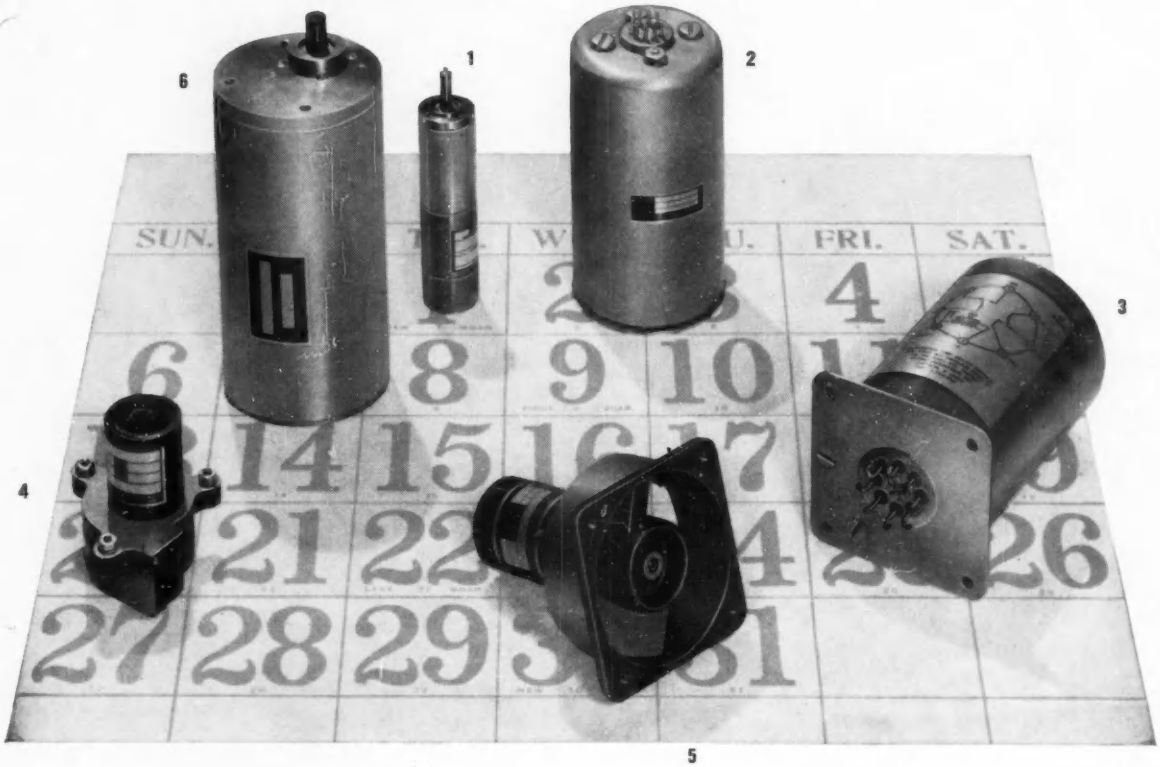


FIG. 3. Rear view shows how two heads on concentric arms are displaced relative to one another. Signals are brought out via slipring brushes.



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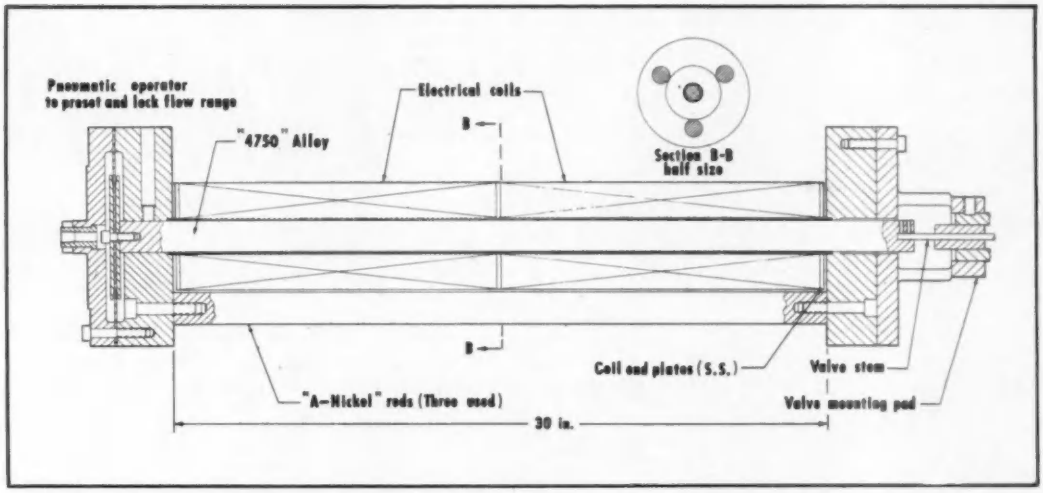
Magnetostriction Adds Precision Control to High-Pressure Valve

ROBERT W. ELLISON, Reaction Motors, Inc.



Magnetostriction high-pressure valve operator has response exceeding 1,000 cps, position repeatability in the order of 0.1 microinch. Positioning range: 0.003 in.

At pressures approaching 30,000 psi, valves formed by a cone seating on the edge of a circular hole produce sizable flows when the cone is out of contact with the seat over only a fraction of the seating circle. The valve stem must therefore be positioned very precisely if flow control is to be accurate. An unusual valve operator, designed to assure this, is based on the principle of magnetostriction. It has been found capable of positioning valves to an accuracy of better than one millionth of an inch. It fact, precision flow measurement made on the valve showed repeatability of flow settings to be as good as or better than the accuracy of the flow instruments used, or one percent of the flow rate. Referred to mechanical position, this would indicate a repeatability of the order of 0.1 microinch.

The valve operator has the form shown in the accompanying figure, and the excellent repeatability is attributed to the exactly matched expansion characteristics of "A-nickel" and "4750" alloy. The two materials are used in this arrangement because A-nickel has a negative magnetostrictive coefficient (i.e., it shrinks when placed in a magnetic field) and 4750 has a positive coefficient. The magnetostrictive effect is independent of the direction of the magnetic field, so that no output motion would be possible if both inner and outer rods were of the same material. For the design shown, the total stroke due to magnetostriction and to pressure acting on the valve stem is in the order of 0.003 in. for rods 30 in. long.

The pneumatic operator at the left in the drawing was used to position the valve stem to about the center of its operating range by balancing the hydraulic force acting on the valve. Mechanical screws could not be used for this adjustment because screws of fine enough pitch do not have the strength to hold the high forces involved.

The frequency response of the 30-in. operator exceeds 1,000 cps. In the original application, the valve was powered by full-wave rectified ac with no filtering except the inductance of the magnetostriction driving coil. Better resolution in pressure let-down control is obtained by shunting a capacitor across the driving coil to resonate at the ripple frequency. Because the magnetostrictive effect is independent of the direction of the applied magnetic field, the operator acts as a frequency doubler and the valve dithers at 240 cps, i.e., at twice the frequency of the applied ripple. The dither occurs about an operating point that depends on the effective dc value of the full-wave current waveform and on the operating point. This nonlinear relationship is difficult to calculate but easy to calibrate.

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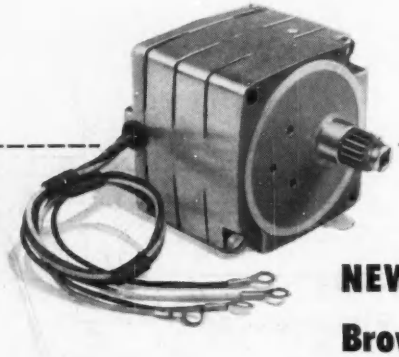

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330	44:1	4	10	7.6	.11	70
148	10:1	5	20	7.0	.11	70
44	30:1	15	60	7.6	.11	70
22	60:1	30	120	7.6	.11	70

SYNCHRONOUS

RPM†	Gear Ratio	Pull-In Torque, Min. (oz.-in.)	Continuous Torque (oz.-in.)	Power (watts) Loaded	Current (amps) Loaded	Temp. Rise Reg. F.
180	10:1	12	12	19	.21	100
180	10:1	3.5	4	13	.11	65
90	20:1	14	12	11	.095	55
60	30:1	13.5	12	13	.11	65
30	60:1	27.5	12	13	.11	65

†1/6 less at 50 cycles. Some speeds available at 25 cycles.

††6.0 watts in field winding, balance in amplifier winding.

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Magnetic Fields Affect Strain Gages

Serious errors in strain measurements on electrical machines and magnets can result from the effect of magnetic fields on Elinvar-wire resistance strain gages. Sensitive strain measurements required on the magnet support structure of the largest U.S. proton accelerator, the Bevatron, launched an investigation to determine the magnitude of this effect. The results are set out here.

JACK GUNN and
EDWARD BILLINGHURST
University of California, Berkeley

While modifying the Bevatron, proton accelerator at the University of California's Radiation Laboratory, it became necessary to make some highly sensitive strain measurements on the magnet support structure. Twenty-five bonded-wire Elinvar resistance strain gages were mounted on five spherical-ended aluminum columns which could transmit only compressive loads, Figure 1. The load cell was calibrated against a universal testing machine and then installed in the Bevatron.

Initial measurements of static and assembly loads gave excellent correlation with calculated values. There was some concern, however, about the possibility of magnetoresitive effects, and tests revealed that changes in the magnetic field alone produced changes in resistance of the same order of magnitude as the changes to be expected from the strain to be measured.

It was found that considerable work had been done previously to determine the magnitude of these effects[1], but that quantitative application to strain gages was difficult because the effects depend upon the degree to which the material has been cold-worked.

Available information

A current carrying ferromagnetic conductor changes its resistance under the influence of an external magnetic field; this change, called the magnetoresistive effect, may be either positive or negative depending upon the material of the conductor and its orientation with respect to the magnetic flux. And since it unbalances a strain-gage bridge, it produces a spurious indication of strain.

When the magnetic field is parallel, in either sense, to the conductor, the resistance increases with field strength up to some saturation value of flux. At extremely high fields, the resistance may tend to decrease again. However, when the field is normal to the conductor, and hence to the current, the resistivity usually decreases with increasing fields.

Magnetostriction, exhibited by iron, nickel, cobalt, and the "Huessler alloys", is really several effects, among them the Joule effect, which is the change in dimension of a ferromagnetic material along the axis of the applied magnetic field. The magnetostriction is said to be positive when the material increases its dimension as the field is increased. Iron has a positive magnetostriction, nickel negative; and iron-nickel alloys either, depending upon the composition.

Externally applied strains also affect the material's resistivity. This "elastoresistance" forms the basis for the use of wire resistance gages for the measurement of strain.

Elastoresistive and magnetoresistive effects are interrelated. The magnitude of the change in resistance due to a magnetic field will be different for a strained than for an unstrained specimen. In positive magnetostrictive materials, the change of resistance with a parallel field will be less as the external tension of the gage increases. This is because the magnetorestrictive effect is caused primarily by reorientation of the magnetic domains in the material. In unstrained metals, the domains are randomly oriented, so that the magnetic field can have a strong effect. Tensile strain tends to line up the domains in the direction of strain, thus leaving fewer domains available for orientation by the flux and decreasing the magnetic effect. If the strain is large enough, the magnetoresistive effect will become negligible. With negative magnetorestrictive materials ,the converse is true. The effects of external compressive strains are the reverse of those for tension.

Under the conditions in most strain-gage applications, other magnetic effects, such as the Hall effect, ferromagnetic attraction, and induction at frequencies other than that of the bridge carrier, apparently are negligible.

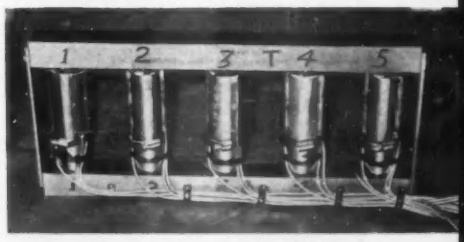


FIG. 1. Strain-gage load-cell has five aluminum columns, 25 gages under protective covers.

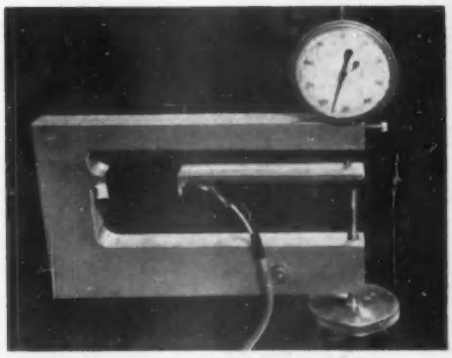
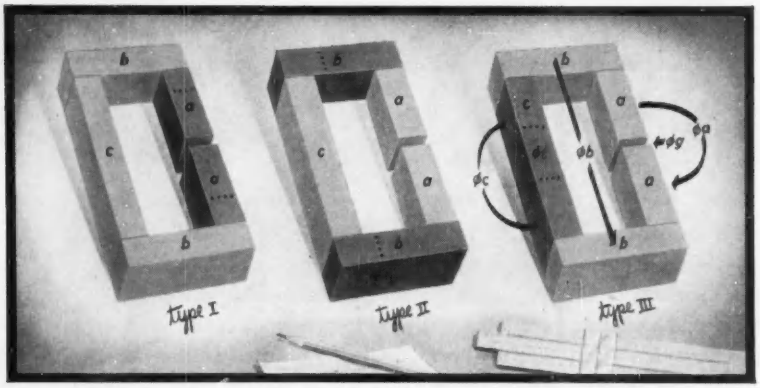


FIG. 2. Test equipment for applying a known deflection to cantilever beam on which test gage is mounted.

Experimental data

This information is difficult to apply directly to strain gages, making an experimental calibration necessary. Tests in a known magnetic field were conducted using bonded-wire resistance strain gages made of four different alloys: Elinvar (57 percent iron, 34 percent nickel); Constantan; 92 percent platinum with 8 percent tung-



How You Can Save Time Estimating Leakage Factors for Magnetic Circuits

Computing even approximate values for leakage flux in magnetic circuits is a time consuming job. The research department of Indiana Steel recently undertook a series of studies, supported by the U.S. Air Force, to simplify these computations. Dr. R. K. Tenzer reported the results of this work, which reduce the time in computing leakage flux up to 90% by diminishing the number of mathematical operations necessary.

The investigations were done on circuits with permanent magnets; the results were also found applicable to unsaturated electromagnetic circuits when the coil-covered parts were treated as permanent magnet parts.

After checking values obtained by this method with actual measured values for many Type I, II, and III magnetic circuits, deviations were found to be less than ± 10%.

Leakage Flux, Leakage Factor

Because of magnetic leakage, only a part of the total flux through the neutral zone of the permanent magnet is found in the air gap. The difference between these two values is known as leakage flux. Mathematically this is:

$$\phi_L = \phi_t - \phi_g. \tag{1}$$

In practical design, leakage is best considered as a factor stated thus:

$$\sigma = \frac{\phi_t}{\phi_g} = 1 + \frac{\phi_L}{\phi_g}. \tag{2}$$

For simplification, the flux can be assumed to follow three basic, probable paths: ϕ_a between parts a, ϕ_b between parts b, and ϕ_c along part c. The equation above then becomes:

$$\sigma = 1 + \frac{\phi_a + \phi_b + \phi_c}{\phi_g}. \tag{3}$$

With $\phi = mmf \times P$, this formula can be written:

$$\sigma = 1 + \frac{1}{P_g}\left(\frac{mmf_a}{mmf_g}P_a + \frac{mmf_b}{mmf_g}P_b + \frac{mmf_c}{mmf_g}P_c\right). \tag{4}$$

Letting the *mmf* ratios be denoted by K,

$$\sigma = 1 + \frac{1}{P_g}\left(K_aP_a + K_bP_b + K_cP_c\right). \tag{5}$$

This becomes the basic equation for numerical calculations of leakage factors after introducing simple expressions for leakage permeances and mmf ratios.

Simplified Leakage Permeances

The following formulas have been found satisfactory for leakage permeances between soft steel parts:

$$P_a = 1.7 \times U_a \times \frac{a}{a + L_g} \text{ where } U \text{ is} \tag{6}$$

cross-section perimeter;

$$P_b = 1.4 \times b \times \sqrt{\frac{U_b}{c} + .25} \tag{7}$$

where U_b/c is greater than .25 and less than 4. The total length of part b is used.

Since permanent magnets have a neutral zone which does not contribute to leakage, the value of 2/3 of the magnet's total length is used when computing leakage permeances—this is the effective length a' and b' to compute P'; thus the two equations above become:

$$P'_a = 1.7\ U_a \frac{.67a}{.67a + L_g} \tag{6a}$$

and

$$P'_b = 1.4 \times .67b\sqrt{\frac{U_b}{c} + .25} = .67\ P_b. \tag{7a}$$

When part c consists of a permanent magnet (Type III) its permeance can be calculated as:

$$P_c = .5\ U_c. \tag{8}$$

The permeance of the air gap itself is

$$P_g = A_g/L_g. \tag{9}$$

Simplified MMF Ratios

Simplifying the *mmf* ratios is done by neglecting the reluctance in *soft steel parts;* so

$$mmf_a = mmf_b = mmf_g \text{ or } K_a = K_b = 1$$
$$(mmf_c = 0 \text{ so } K_c = 0). \tag{10}$$

Since the *mmf along permanent magnet parts* is not constant, integral values ($\overline{mmf}$) are used. Experiments showed that 2/3 of the mmf_g was the effective *mmf* for leakage flux between permanent magnet parts; thus

$$\overline{mmf_a} = \overline{mmf_b} = \overline{mmf_c} = 2/3\ mmf_g$$

or

$$K_a = K_b = K_c = 2/3. \tag{11}$$

Basic Formulas

By inserting the permeances for soft steel into equation (5), the general formula becomes:

$$\sigma = 1 + \frac{L_g}{A_g}\left(K_a \times 1.7\ U_a \frac{a}{a + L_g} + K_b \times 1.4\ b\sqrt{\frac{U_b}{c} + .25} + K_c \times .5\ U_c\right). \tag{12}$$

This formula contains only constants and dimensions; and by the two following rules this can be modified into the three basic equations for the Type I, Type II, and Type III circuits.

Rules: (1) For leakage flux paths between soft steel parts, use total lengths and constant K of 1. (2) For leakage flux paths between permanent magnet parts, use 2/3 of lengths and K of .67.

The following provide the leakage factors for the three types of circuits:

Type I:

$$\sigma = 1 + \frac{L_g}{A_g} \times .67 \times 1.7\ U_a \frac{.67a}{.67a + L_g}$$

Type II:

$$\sigma = 1 + \frac{L_g}{A_g}\left(1.7\ U_a \frac{a}{a + L_g} + .67 \times .67 \times 1.4b\sqrt{\frac{U_b}{c} + .25}\right)$$

Type III:

$$\sigma = 1 + \frac{L_g}{A_g}\left(1.7\ U_a \frac{a}{a + L_g} + 1.4b\sqrt{\frac{U_b}{c} + .25} + .67 \times .5\ U_c\right)$$

For variations on these basic formulas, write today for the April-June issue of *Applied Magnetics* which also shows examples of the formulas in use.

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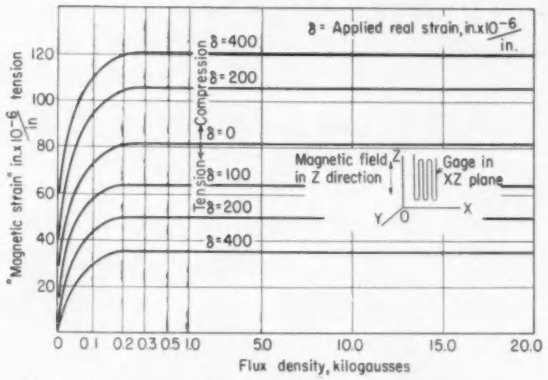

FIG. 3. Magnetoresistive effect in Elinvar plotted as an effective "magnetic strain", for fields parallel to gage.

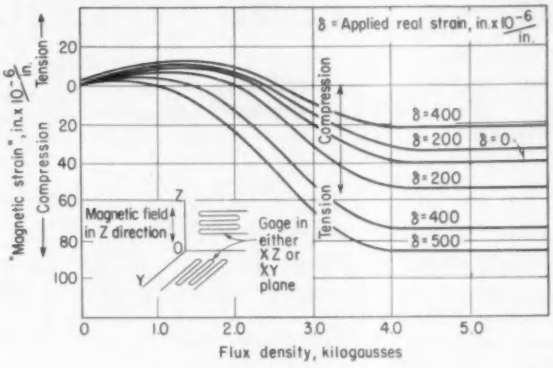

FIG. 4. Magnetoresistive effect in Elinvar plotted as a "magnetic strain", for field perpendicular to gage wires.

sten,* Alloy 1,000*. From these tests quantitative information was obtained concerning the magnetic effects, so that the loads cells could be used with suitable reading corrections.

The tests were performed with the test gages mounted on an aluminum cantilever beam, Figure 2, with an adjusting screw to deflect the beam an amount measured by an opposed dial indicator. The entire test piece was nonferrous so that it could be inserted into a known magnetic field.

The test results are consistent with the foregoing theory. The curves of Figures 3 and 4 show change in resistance (due solely to the magnetic field) as a function of field strength, with applied external strain as a parameter for Elinvar-wire gages. These curves were obtained for each of the three orthogonal orientations of the gage with respect to the field. No attempt was made to measure the combined effects for other orientations. The magnitude of the spurious strains is quite sensitive to small changes in orientation with respect to the magnetic field.

An important result of these tests is that *only the gages of Elinvar showed the magnetoresistive effects.* Thus, the widely used Constantan gages are suitable for applications around magnetic fields.

Applying the higher-sensitivity Elinvar gages is particularly difficult when these gages must be used near magnetic circuits. Wherever possible, the less-sensitive Constantan wire gages should be used.

The Elinvar gages can be used provided the direction and magnitude of the magnetic field are known. Note that under usual conditions (flux less than saturation, magnetomotive force approximately at right angles to the surface) the lines of flux issue at right angles from a ferromagnetic surface. Such use involves a "trial and error" type solution, using the curves presented in Figures 3 and 4.

1. Assume a real strain.
2. Using its curve, find the corresponding "magnetic strain".
3. Algebraically add this "magnetic strain" to the assumed real strain.
4. Compare with observed strain.

For high accuracy work, these curves should be spot-checked to detect possible variations between lots.

* Proprietary alloys of Baldwin-Lima-Hamilton Co.

REFERENCE

1. *FERROMAGNETISM*, H. M. Bozorth, D. Van Nostrand Co., Inc., 1951.

Pneumatics Simplify B-58 Temperature Controls

WILLIAM ARMBRUSTER
Parker Aircraft Co.

Regulating of ventilating duct and compartment temperatures in high-performance aircraft is extremely difficult because of the excessive pressure and temperature ranges normal to the sources of the heating and cooling air. Two typical systems show how pneumatics solve these problems.

Convair's B-58 Hustler is equipped with a number of pneumatic-mechanical systems for controlling temperatures at various points in the compartments and ventilating ducts. In all these systems, cold inlet air is taken aboard through an expansion or cooling turbine and mixed with bleed air from the jet engine. The control problem is unusual because the inlet temperatures and pressures of both hot and cold air supplies vary over wide ranges during normal operation.

The temperature and barometric pressure of the air through which the Hustler flies varies considerably within its operational altitude range. And the temperature and pressure of the hot engine bleed air changes even more markedly, depending on engine speed and acceleration. For example, the air might range from 250 to 600 deg F and from 20 to 200 psig in the short time it takes to go directly into a steep climb from a sharp dive. The inlet air ranges for which the control systems are designed, then, are as follows:

- hot air source—10 to 250 psig; 70 to 600 deg F.
- cold air source—0 to 10 psig; minus 100 to plus 60 deg F.

Low temperature limiter

One of the simpler systems is shown in Figure 1. It maintains the

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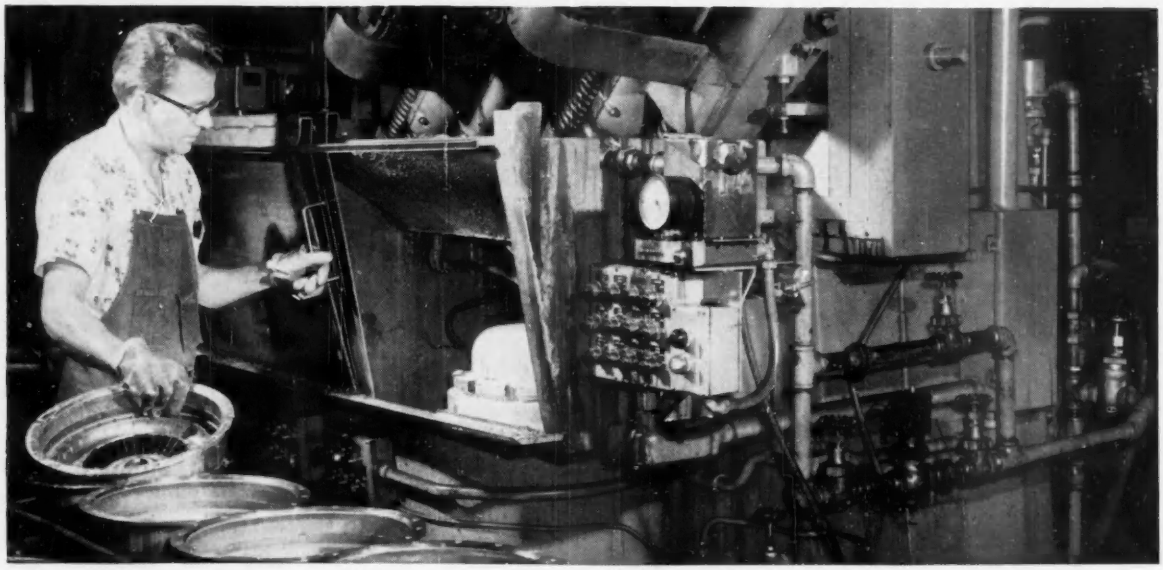

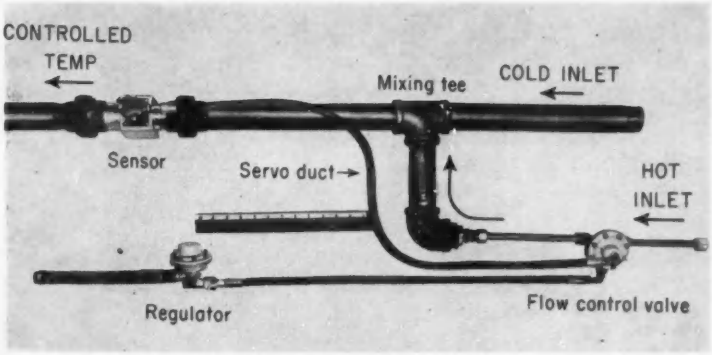

FIG. 1. Laboratory test setup shows entire system for limiting lower temperature of main duct to left of mixing tee. Both cold and hot inlet temperatures and pressures can vary over very wide limits.

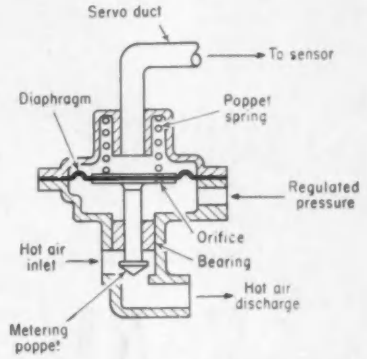

FIG. 2. Operation of diaphragm operated poppet-type flow control valve is described in text.

controlled temperature above 33 deg F, and thus acts as a low-temperature limiter. Hot air is metered into the main duct by the flow-control valve, which is detailed in Figure 2. Because of the high pressures to be metered, this valve must be a poppet type.

The poppet valve is actuated by a spring-load differential diaphragm pierced by a small bleed orifice. Regulated air at 12 psig is supplied to one side of the diaphragm to oppose the spring force and open the valve. If the servo duct is closed, the air on both sides of the diaphragm equalizes at 12 psig so that no pneumatic force results, and the spring holds the poppet valve closed. The air pressure in the servo duct is controlled by the temperature sensor in Figure 3.

The temperature sensor is a cup filled with a liquid that has a high coefficient of thermal expansion. The cup is closed with a diaphragm that moves the poppet valve stem as the liquid expands and contracts. The temperature sensor is adjusted so that it opens the servo duct if the temperature of the cold inlet air drops below 33 deg F. Decreasing air pressure in the servo duct causes the flow-control valve to open, admitting hot air into the main duct. This in turn restricts the air flow in the servo duct, and the pressure on top of the control valve diaphragm increases to reduce the amount of hot air flow through the control valve. If the cold air supply remains below 33 deg F, the sensor remains open at some intermediate position to maintain the mixed air at 33 deg. This system could be designed to limit maximum as well as minimum temperatures from minus 40 to plus 300 deg F.

Multiple control system

The preceding techniques can also be adapted to more complex control problems. Another system on the B-58, for example, uses two sensors and two flow control valves to regulate two points in one ventilating duct to two different temperatures, Figure 4 Here the control requirements were.

- after heater A—60 to 90 deg F
- after heater B—185 to 215 deg F.

Heater A functions most efficiently at 75 plus or minus 15 deg F, heater B at 200 plus or minus 15 deg F. For this reason, the hot air control sensor was placed immediately after the lower temperature heater. The temperature of the air leaving either heater is essentially the same as the temperature inside of the heater. If the temperature leaving heater A falls below 60 deg F, the hot air flow control valve opens enough to raise it to 60 deg.

Conversely, as the air leaving heater B approaches 215 deg F, the cold air control valve admits more cold air into the main duct. Each of the two heaters generates a variable amount of heat, and the changes are independent of one another. Thus, the two temperatures to be controlled depend not only on the proportions of hot and cold air, but also on the total flow within the main duct.

Combined interaction of the two systems thus controls the temperatures leaving the two heaters by varying the total flow as well as the proportions of hot and cold air. The cold air flow control valve in this system is a gate valve because the cold air enters at a low pressure and extreme sensitivity is not needed. In this case, the gate valve has the advantage of lower pressure drop.

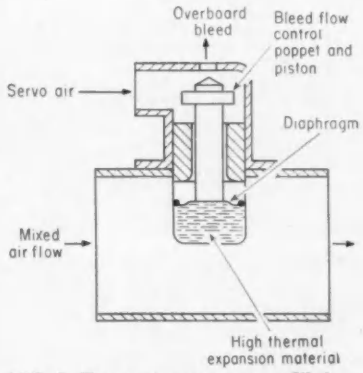

FIG. 3. Temperature sensor uses filled system to actuate servo duct bleed valve.

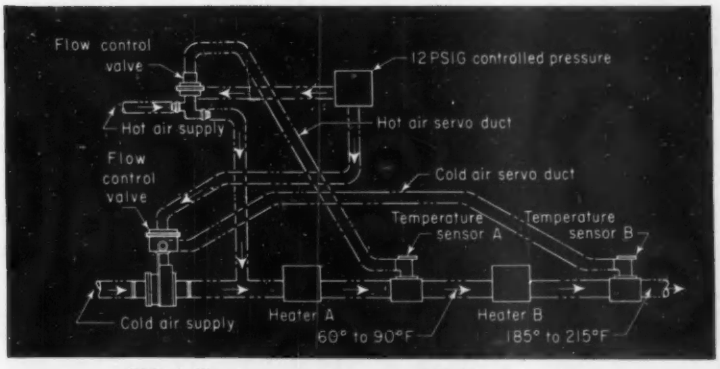

FIG. 4. Two temperatures are controlled by this system, which varies total flow as well as hot-cold ratio.

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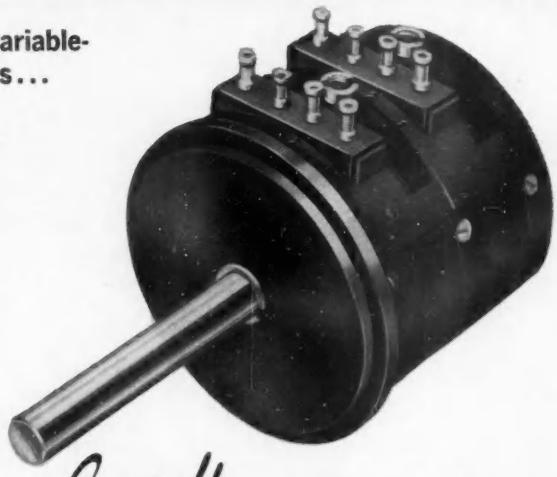

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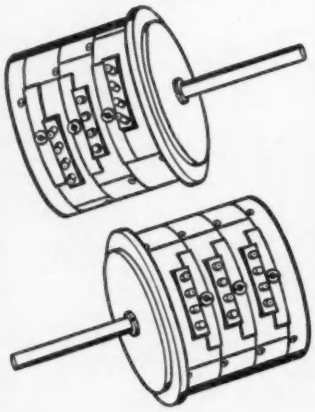

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Depth Single section	0.672	0.578	0.968	1.000	1.000
Each additional cup add	0.375	0.375	0.580	0.580	0.580
Weight (lb.) approx. Single section	0.035	0.060	0.120	0.140	0.280
Each additional cup add	0.015	0.030	0.060	0.070	0.140
Insulation — Breakdown test between terminals and ground for 1 minute	1000 v. a.c./d.c.	1000 v. a.c./d.c.	1000 v. a.c./d.c.	1000 v. a.c./d.c.	1000 v. a.c./d.c.
Resistance Range (Ohms) — Standard	to 20K Ω	to 30K Ω	to 100K Ω	to 100K Ω	to 200K Ω
Resistance Tolerance — Standard	± 5%	± 5%	± 5%	± 5%	± 5%
Linearity	± 1%	±.1% closer Available	± 1% closer Available	0.5% closer Available	0.5% closer Available
Tapers — Submit Requirements	— — —	Available	Available	Available	Available
Taps	Available	Available	Available	Available	Available
Rotation Mechanical Continuous	360°	360°	360°	360°	360°
Rotation Mechanical Limited	as required	as required	as required	as required	as required
Electrical	320° min.	320° min.	320° min.	320° min.	320° min.
Effective	300° ± 2°	300° ± 2°	300° ± 2°	300° ± 2°	300° ± 2°
Torque — Per section Standard (Lower or higher available.)	Less than 1 oz. in.	Less than 1 oz. in.	Less than 1 oz. in.	Less than 1 oz. in.	Less than 1 oz. in.
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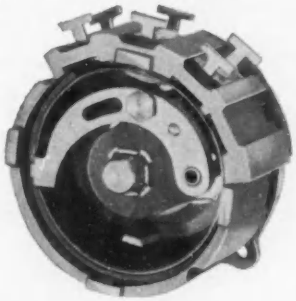
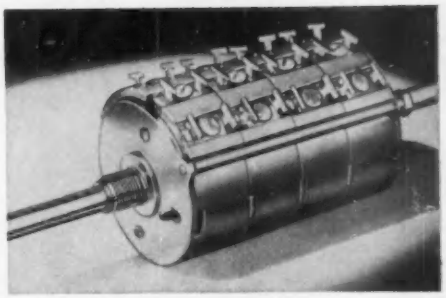
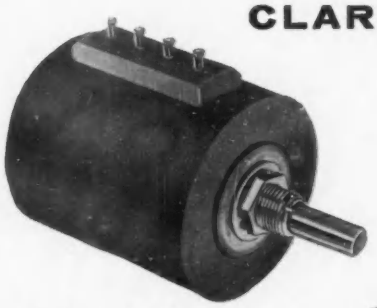




Resistance Range (Linear)	10 to 100,000 ohms.
(Non-linear)	Max. 350 ohms per degree of rotation.
Resistance Tolerance	Standard overall ±5% Special, ±0.5%.
Linearity (standard)	±1%; ±0.5% special.
Power Rating	3 watts, at 40° C.
Rotation (Effective)	280°; Max. 358°.
Rotation (Mechanical)	Up to 340° with stops. Continuous if desired.
Torque	1 oz./in. max. per section.

CLAROSTAT SERIES 55



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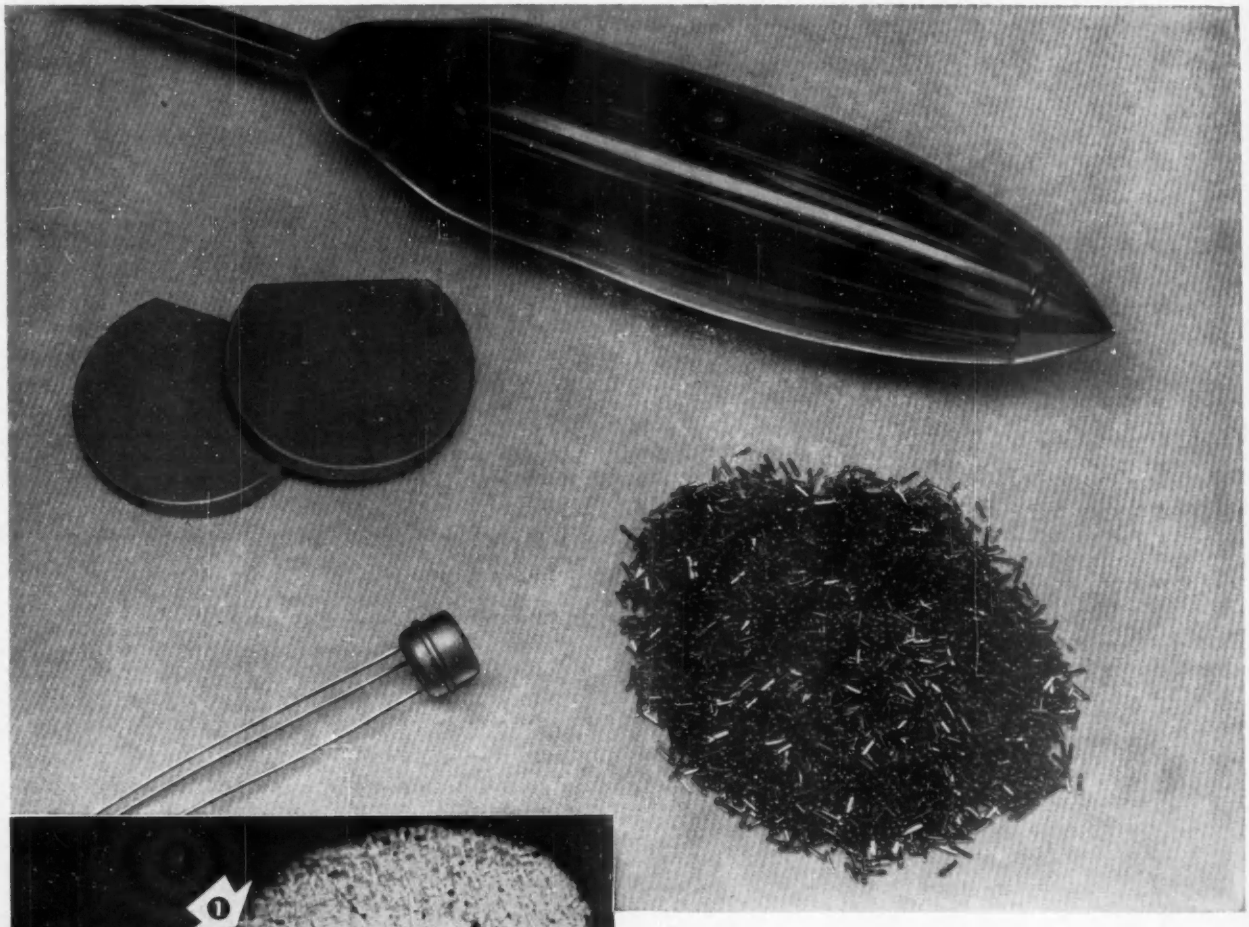
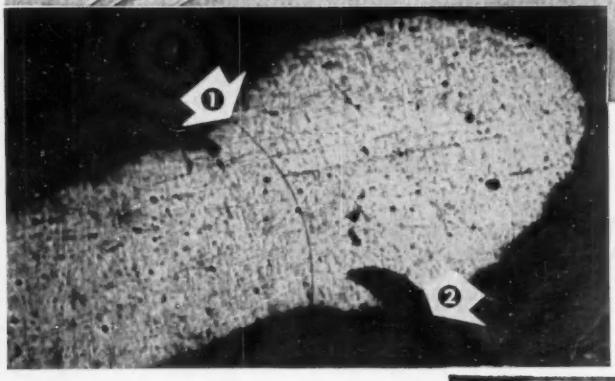
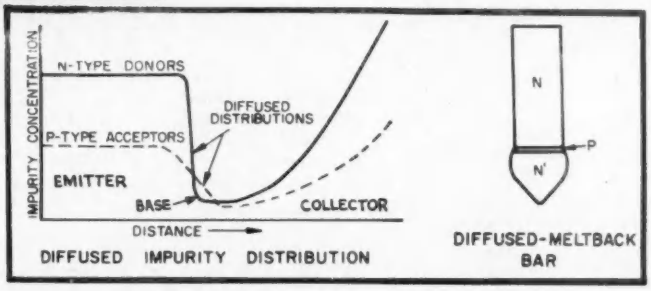




Before going through the diffused-meltback operation, a crystal of silicon is sawed into wafer-form: wafers are then diced to produce 4000 to 5000 individual silicon bars. Photomicrograph at left shows size-comparison of a silicon NPN bar, or pellet, with human hair (Arrow 2). "Tear drop" at end of bar is formed during meltback process. Micro-thin base, or "P", region (Arrow 1) is created through G-E diffusion technique. Base regions of 2-micron size are made with relative ease.

Curves illustrating impurity distribution after diffusion. P-type impurities in the high concentration side of the meltback junction diffuse, within solid semiconductor, into "plateau" region of low impurity concentration. High resistivity "plateau" contributes to elimination of punch-thru effects.



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Opens the door to high frequency performance. Diffusion of a melted-back silicon bar, or pellet, is the final step in the diffused-meltback process. It's the stage in which the micro-thin base, or "P" region is formed, establishing the final NPN transistor structure. Because the actual diffusion is accomplished over a high temperature heating cycle lasting several hours, the need for split-second accuracy is eliminated. The result is a high degree of process control.

By proper choice of the initial impurity concentrations and the time and temperature of the diffusion cycle, heavily-doped base regions as thin as 2 microns are easily obtained. *These micro-thin, uniform base regions are the "open-sesame" to extremely reliable high frequency transistor performance.*

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2N431	(formerly 4JD4A4)	9 to 30
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High current gain. Silicon NPN transistors feature inherent high current gains and high frequency cut-offs. The diffused meltback process permits mass production, since it combines the principles of impurity segregation and solid-state diffusion.

G-E silicon NPN transistors are nominally rated for 25 megacycles, but with useful gain to 50 megacycles—the highest frequencies offered by any mass-produced silicon NPN triode on the market today. All production units are aged at extremely high temperatures for over 150 hours. This is to provide maximum stability of I_{co} and current gain (beta).

The header assemblies of G-E silicon NPN transistors are constructed of high-purity materials. A gold-silicon alloy is used for end connections: the base lead is pure aluminum. There are no solders or fluxes, eliminating any danger of transistor "sleeping sickness" caused by corrosion at soldered junction points.

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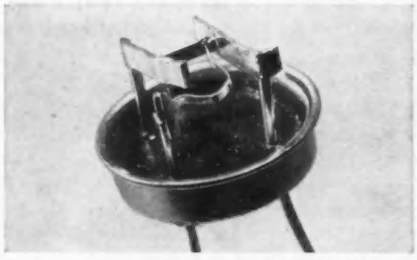
With well-controlled high frequency characteristics and a low saturation resistance of 20 ohms, G-E silicon NPN transistors are "naturals" for switching applications and linear amplifier use.

Would you like complete specification information? Please contact your nearest G-E Semiconductor Products district office, or write to General Electric Company, Semiconductor Products, Section S1687, Electronics Park, Syracuse, N. Y.



View of uncapped G-E silicon NPN diffused-meltback transistor, showing mounted silicon bar with aluminum base lead connected. Bar ends attached using a gold-alloy mounting technique. No solders or fluxes are used.

Diffusion furnace. Operator places quartz vials, with large quantity of silicon bars, in furnace. Diffusion occurs through high-temperature heating cycle lasting several hours.

An aging oven in which G-E silicon NPN transistors are aged at extremely high temperatures for over 150 hours. Provides maximum stability of I_{co} and current gain (beta).

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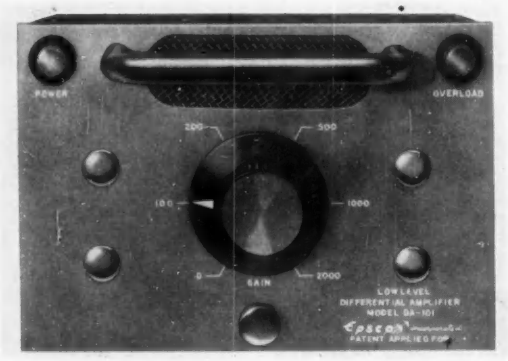
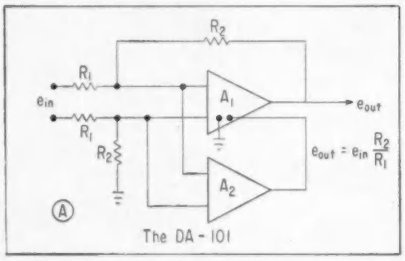
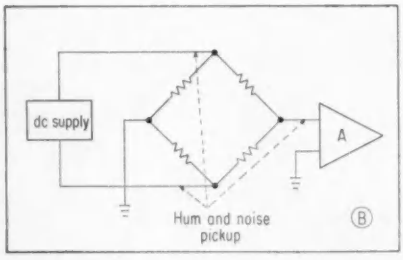
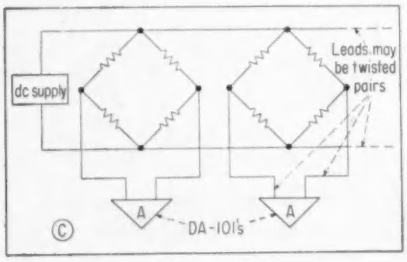








TRUE DIFFERENTIAL AMPLIFIER reflects common-mode noise and hum pickup.

The Epsco Model DA-101 wide-band differential amplifier, photo left, handles low-level signals, *including pulse signals*, without noise or hum pickup. It provides high gain and stability for strain-gage and thermocouple applications.

Noise is 6 microvolts referred to the input with a bandwidth of 50 kc at the 3-db point and at 20,000 ohms differential input impedance. Static common-mode rejection is over 100,000 to 1. Gain is adjustable in steps from 100X to 2,000X, and is accurate within 0.1 percent. Linearity is within plus or minus 0.05 percent.

In direct-coupled amplifiers, high-gain stability is the result of large amounts of negative feedback. Gain then is essentially independent of all factors except the precision of the feedback resistors. Block diagram A illustrates this principle. The feedback resistor is R_2, and since this is a differential input amplifier, there are two equal branches of R_1 and R_2. The actual input to the high-gain, direct-coupled amplifier, A_1, is produced between the summing junctions of these two equal branches. As indicated, amplifier output is determined by the ratio of R_2 to R_1. Gain is easily changed.

Chopper stabilization corrects for any output drift due to unbalance in the differential input stage. As shown, the differential signal between the summing junctions is also fed to a chopper amplifier, A_2. This signal, proportional to any output drift, generates a corrective voltage that is fed back to the main amplifier, where it corrects the unbalance.

Diagrams *B* and *C* illustrate the advantages of this new amplifier in strain-gage applications. In the past it has been necessary to use a separate power supply for each strain gage whenever high frequency response and/or stable gain characteristics were required. A common supply was not practical because balancing of one bridge would unbalance the others. A single-ended amplifier was used in these applications, as shown in *B*. Note that any change in the bridge elements will change the impedance from the supply lines to ground. Such arrangements are also quite susceptible to hum and noise pickup at the points indicated. Shielding and capacitive isolation of the power supply is a must.

Compare this with the arrangement shown in diagram *C*. Here, a single power supply can be used to calculate an entire test facility. Power-supply noise and hum appear as common-mode signals and are therefore rejected in the amplifier outputs. Because of this, twisted leads may be used for both power supply and the differential amplifiers.

In thermocouple applications, use of the Model DA-101 also eliminates any error due to an uncertain emf generated in a ground path.—Epsco, Inc., Boston, Mass.

Circle No. 1 on reply card

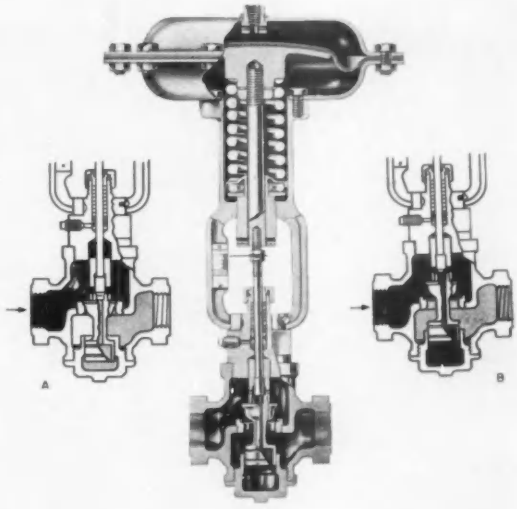
NEW BALANCED VALVE fills control need.

The Schade Series 30 control valves combine the balance and control of double-seated valves with the tight closing, dead-end service found only in single-seated valves. To regulate flow accurately and with sensitivity, a control valve should be unaffected by the pressure differential across its seat and disc. In an unbalanced valve, this pressure differential forces the stem into an incorrect position. Only in the closed position does pressure help.

To effect both tight shutoff and excellent balance when open, this new, single-seated valve uses an internal balancing pilot that instantaneously equalizes the pressure on the disc as soon as the valve starts to open. Sketch *A* shows valve and pilot tightly closed. Sketch *B* shows valve and pilot fully opened. Note that in any open position of the valve, pressure must be equal on both sides of the disc.

Series 30 valves will be supplied with either direct- or reverse-acting diaphragm motors made by Kieley & Mueller. —Schade Valve Mfg. Co., Philadelphia, Pa.

Circle No. 2 on reply card

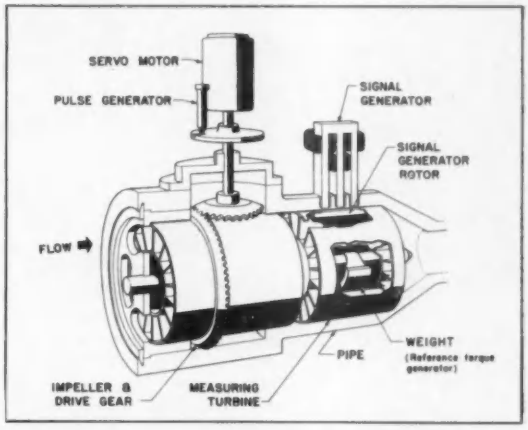


MASS FLOWMETER has digital output.

The DIGIMAF, a new digital mass flowmeter, accurately measures true mass flow of fluids at extreme temperatures.

The design retains the change-of-momentum principle. A change in mass flow tends to rotate the measuring turbine. This produces a change in the signal generator output which, through the servomotor, corrects the impeller speed and balances the upsetting torque. Reference torque is provided by a mass suspended on a supporting arm fixed to the turbine shaft. Length of this arm changes with temperature, producing a change in the reference torque. But since tube diameter also is affected by temperature, the indicated mass flow is still correct. Output of the device is a pulse frequency, proportional to impeller speed. This is fed to a digital readout device.—Inertial Instruments, Inc., Santa Monica, Calif.

Circle No. 3 on reply card



PARTICLE COUNTER cuts time and error.

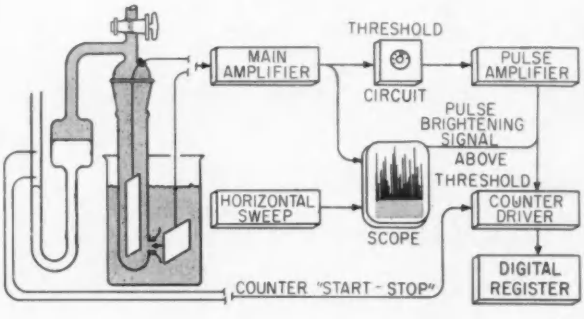
Though intended for the medical and biological fields, this new particle counter and size distribution analyzer should find wide use in the field of industrial measurements.

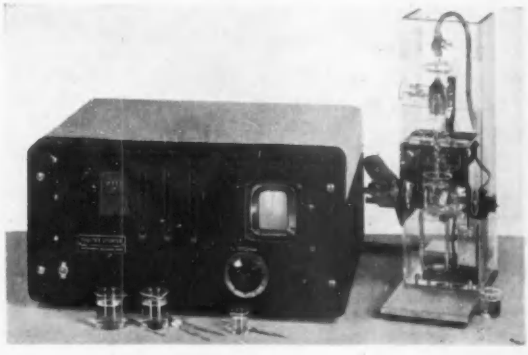
Operation involves the forced passage of a fluid suspension of particles through a small aperture having an electrode on each side. As each particle passes through, aperture resistance changes in proportion to particle size, and the resultant series of pulses is electronically scaled and counted. Curves of cumulative particle frequency vs. particle size are obtained directly. From these, weight and area distributions are derived. Cuts below show a schematic and photo.

Aperatures from 35 to 400 microns are available for counting particles ranging in size from 0.7 to 200 microns. Size ranges of 20 to 1 are easily handled with a single aperture, and almost any type of particle may be measured, all that is required being a fluid suspending medium. Either the fluid or the particle material may be the better conductor.

Applications include particle count and size distribution studies.—Coulter Industrial Sales Co., Elmhurst, Ill.

Circle No. 4 on reply card





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NEW PRODUCTS

RESEARCH, TEST & DEVELOPMENT

MEASURES DEAD SPACE

Precise measurement of dead space in hydraulic servo valves is now possible, thanks to the test stand shown here. Unlike conventional equipment, this device measures dead space under actual operating pressures, thus providing precise data on edge conditions as well as on the location of the face on the land. Elements include a holding fixture for oscillating the valve piston, an electronic gaging system for recording piston motion, and a pressure sensing system for indicating opening and closing points of the valve. It operates on a 110-volt, 60-cps supply and requires a hydraulic pressure of 3,000-psi maximum. Three measurement ranges are provided.—Hesse-Eastern Div. of Flightex Fabrics, Inc., Cambridge, Mass.

Circle No. 5 on reply card

LOW-COST ANALYZER

A $750 laboratory vapor phase analyzer for gas chromatography handles helium, nitrogen, hydrogen, dried air, and a variety of other carrier gases. The detector is a Gow-Mac diffusion type thermal conductivity cell with a time constant of less than 1 sec and a negligible drift. Pressure in a 10-ft coiled column may be varied from 0 to 30 psig. Column flow is adjustable from 0 to 80 ml per min. The bridge balance has both coarse and fine adjustments. Sensitivity may be changed during analysis to reduce or enlarge peaks to a usable area. Liquid samples may be introduced in 10-, 20-, and 40-microliter quantities. Gas samples are put in through a 0.5-to-2.0-cc constant-volume valve. Binding posts are provided for direct connection to a standard 0-to-10-mv recorder.—Central Scientific Co., Chicago, Ill.

Circle No. 6 on reply card

10 CPS to 100 KC METER

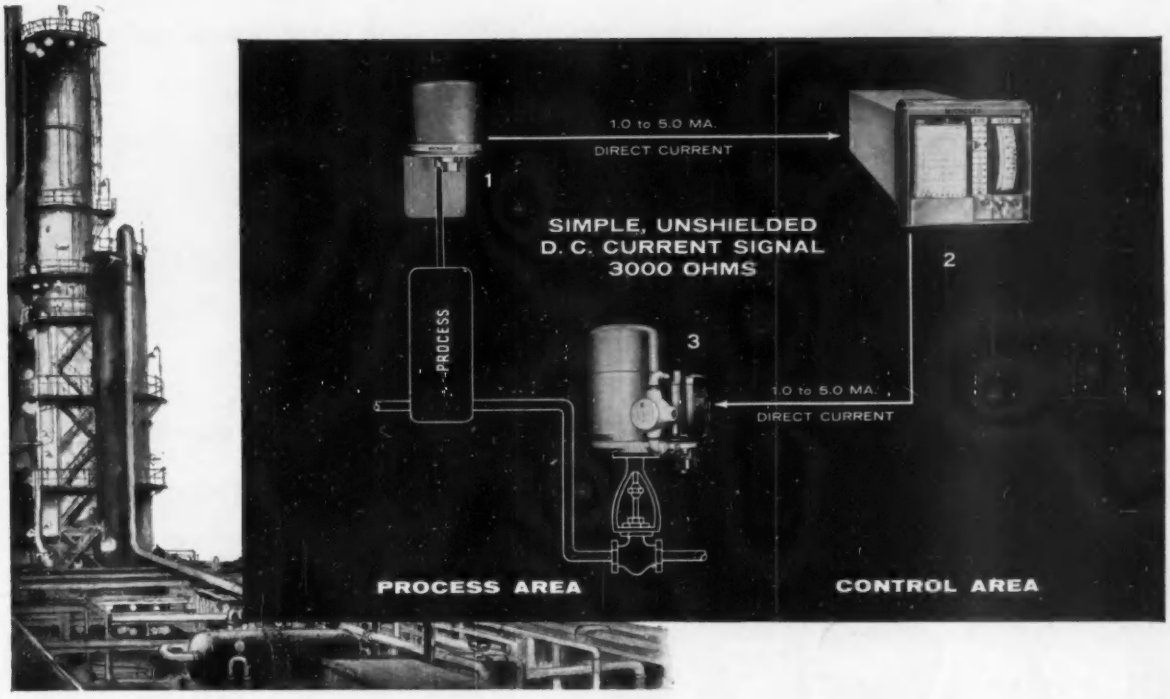
This new transistorized meter measures frequencies in the range of from 10 cps to 100 kc and is accurate to within 2 percent regardless of wave shape, down to a 1-percent duty cycle. Seven full volt ranges, assuring easy and accurate readability, are: 100 cps, 300 cps, 1 kc, 3 kc, 10 kc, 30 kc, and 100 kc. Minimum input voltage is 0.1 volt rms; maximum is 120 volts. Instrument measures 8¾ by 5¾ by 4 in., and sells for $125.—Teletronics Laboratory, Inc., Westbury, Long Island.

Circle No. 7 on reply card

TRANSDUCER CALIBRATOR

Ten four-arm strain-gage bridge- or resistive-type pickups may be calibrated individually or simultaneously with the Model 228 rack-mounted balance unit, designed for large-scale instrumentation systems. Features includes individual plug-in calibration registers, inserted from the front through a hinged door, and precision 10-turn balance and sensitivity potentiometers, provided with knurled finger locks for maintaining settings. Individual or common voltage supplies of 0 to 30 volts may be used. The system is designed for four-arm resistive transducers of 120 ohms or more.—Consolidated Avionics Corp., Westbury, N. Y.

Circle No. 8 on reply card



Let's look at a typical control loop of the 'American-Microsen' *ELECTRONIC PROCESS CONTROL SYSTEM*

This all-electronic dc system of miniature-type units assures the instrument engineer of 1) better control; 2) greater flexibility; 3) lower initial costs; 4) lower operating costs. The typical control loop above demonstrates the simplicity and functions of the system.

1. *Transmitter.* 'American-Microsen' transmitters are used for measuring pressure, temperature, differential pressure, liquid level, flow, and other process variables. The "Microsen" balance creates a stable dc signal for long distance transmission. Transmitters have no bearing pivots or linkages — assuring sensitivity and repeatability of measurement. Small size is made possible by printed circuitry and miniaturized components. The unit can be installed on meter piping, pipe pedestal or vertical surface.

2. *Controller.* A single unit combines all functions of measuring and recording or indicating the input signal; producing the control signal; and allowing manual-automatic process operation. Separate plug-in chassis provides the following functions: *A.* Records or indicates process variable. Strip or card chart recorder chassis available. *B.* Produces proportional, reset and rate control actions to regulate the variable. All control settings are calibrated. *C.* Permits switching to manual operation during start-up or emergency conditions, with true "bumpless" transfer from manual to automatic control.

Transistorized design increases reliability and service life. Miniaturization and consolidation of control functions reduces panel cost and wiring expense.

3. *Electro-Hydraulic Control Valve Operator.* A power unit with position feedback that operates slip-stem control valves. No compressed air is needed. Mountable on standard yokes supplied with conventional slip-stem control valves with bodies of single or double-seated construction, with V-port, parabolic, needle and equal percentage plugs, including valves of 4" stroke, and force available up to 3,250 lbs.

Where required, the American-Microsen Electro-Pneumatic Valve Positioner or the Electro-Pneumatic Transducer can be supplied.

In automating your processes for higher product quality and greater operating economy, you want the better control and simplified servicing provided by the American-Microsen Electronic Process Control System. We invite you to meet with one of our sales engineers to determine the best equipment for your service. Write for literature.

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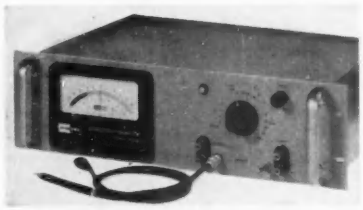
NEW PRODUCTS

NEW DYNAMOMETER

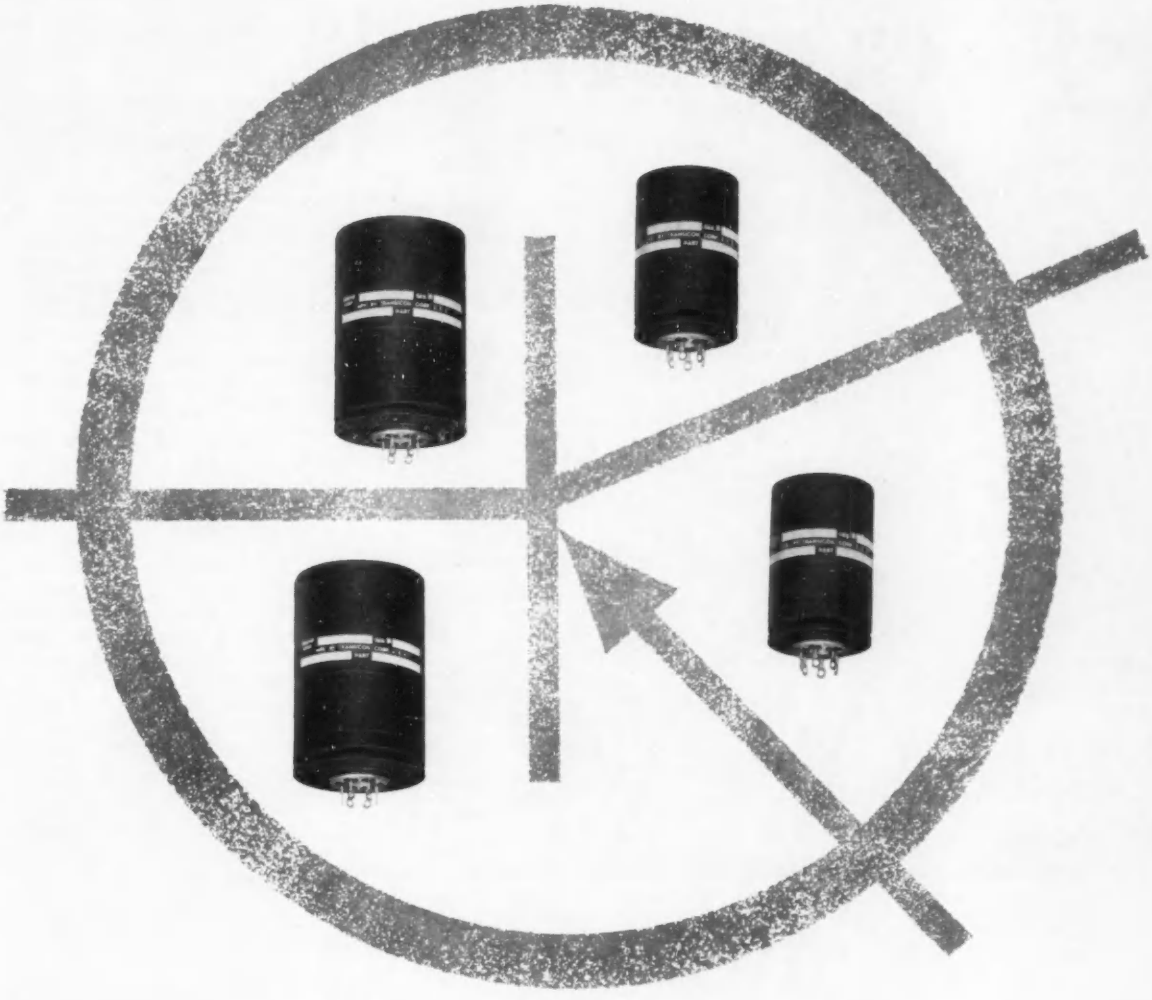
Till the arrival of this new dynamometer, which operates on the principle of feedback torque control, testing of shaded-pole motors on conventional dynamometers was limited by the reverse "knee" of torque, occurring near the maximum load range. When the tach generator on the dynamometer detects a drop in speed, a corresponding drop in load torque is instantaneously effected and the motor stabilized in any portion of the curve. Motors may be tested for maximum speed down as low as 100 rpm. Speed is continually monitored on an electronic tachometer and indicated at accuracies within 0.5 percent. Speed pickup is photoelectric, and no error due to tachometer generator or spurious magnetic losses is present. Seven basic models are available with torque ranges from 750 oz-in. to as low as 1 oz-in. full-scale.—Magtrol, Inc., Niagara Falls, N. Y.

Circle No. 9 on reply card



DC METER-AMPLIFIER

This new Model 203AR, combination dc microvoltmeter, microammeter, and low-level dc amplifier, is partially transistorized and uses chopper circuitry to provide stability and high input impedance. Fifteen voltage ranges cover 100 microvolts full-scale to 1,000 volts full-scale, and 19 current ranges cover 1 millimicroamp full-scale to 1 amp full-scale. An uncluttered, zero-center meter face indicates polarity on two mirrored scales which will cover all ranges. Input impedance is



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new TRANSISTORIZED servo amplifiers

Transicoil introduces four new, completely transistorized Servo Amplifiers for use in applications requiring the highest order of precision, miniaturization, and dependability. Measuring a mere 3″ or less in length, these servo amplifiers help you keep assemblies within the severe space limitations of many types of military and industrial applications.

The new amplifiers produce voltage gains of 100:1, 200:1, 2000:1, and 4000:1. They are specifically engineered for use with Transicoil Motors and Motor Driven Induction Generators in sizes 8, 9, 11, 15, and 18. To insure maximum accuracy and dependability, Transicoil supplies these servo amplifiers only as part of its own miniaturized servo assemblies. All amplifier units are hermetically sealed and are made with the same care, materials, and precision that have made Transicoil a recognized leader in the manufacture of custom built servo components and assemblies.

For more complete information on Transicoil's new Transistorized Servo Amplifiers, write for Bulletin 101. And when you have control problems involving miniaturization or control complexity, be sure to get in touch with Transicoil. You profit most when you let Transicoil design and supply your complete servo package. You will be under no obligation—you pay only for results, on a fixed fee basis, for equipment delivered and operating properly.

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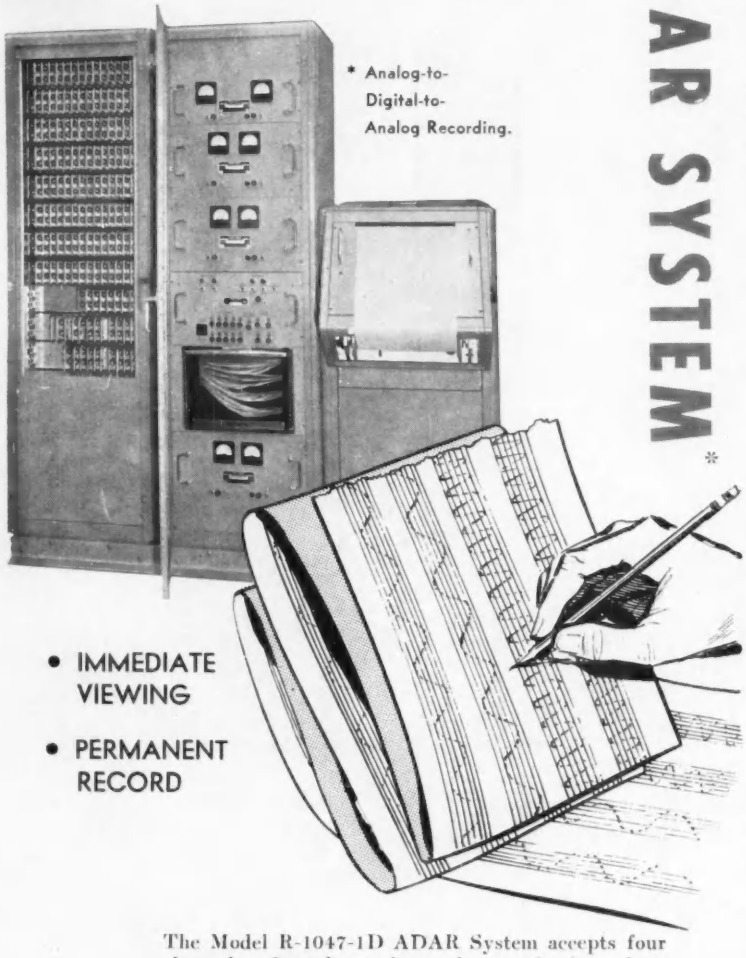
4 CHANNEL ADAR SYSTEM *



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The Model R-1047-1D ADAR System accepts four channels of analog voltage data and plots these data as four non-overlapping quantized analog traces, each trace resolved to one part in 64. The system is particularly suited to the plotting of transient phenomena since the multistylus plotting technique eliminates problems due to damping, overshoot, resonance, and other mechanical limitations. The chart requires no processing, and the plotted data are therefore available for immediate viewing and intepretation.

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NEW PRODUCTS

10 megohms on the 30-mv range or below and 100 megohms on the 100-mv to 1,000-volt ranges. Impedance accuracy is within plus or minus 1.5 percent. Front output terminals allow it to be used as a dc amplifier. Characteristics include a maximum gain of 80 db, maximum output capability of plus or minus 1 volt across 500 ohms or more, output impedance of less than 2 ohms, and equivalent input drift of less than 10 microvolts. Kin-Tel, San Diego, Calif.

Circle No. 10 on reply card

ZEROS SYNCHROS

A new zeroing device, the Synchro-Null Model LD 101, features universal adaptability, simple operation, and excellent zeroing accuracy. The $260 unit is readily applicable to 110-volt/60-cps, 110-volt/400-cps, and 26-volt/400-cps synchros of all standard types and sizes. It is only 7 in. high by 19 in. wide by 7 in. deep, and weighs 14 lb uncrated.—Advance Industries, Inc., Cambridge, Mass.

Circle No. 11 on reply card

MEASUREMENT & DATA TRANSMISSION

NEW CONVERTER

Designed for reliable and accurate high-speed computing and recording in airborne, military, and industrial applications, this new shaft-angle converter provides a binary decimal readout of 1 in 3,600 counts at 40 codes per revolution of the input shaft. Intermittent gearing and precision bearings provide extremely low driving torque. The input shaft can rotate at speeds up to 300 rpm in either direction and permits digital output coding "on-the-fly". Code drum is

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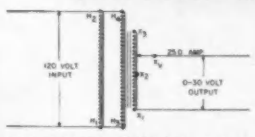
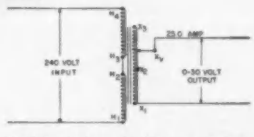
TYPE LW136

TYPE LW136-3

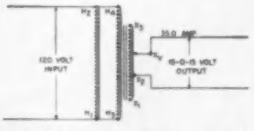
SINGLE PHASE



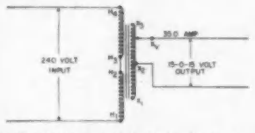
INPUT 120 Volt, 50/60 Cycle, 1 Phase
OUTPUT 0-30 Volt, 25 Amp., 0.75 KVA



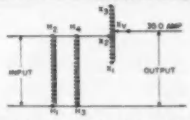
INPUT 240 Volt, 50/60 Cycle, 1 Phase
OUTPUT 0-30 Volt, 25 Amp., 0.75 KVA



INPUT 120 Volt, 50/60 Cycle, 1 Phase
OUTPUT 15-0-15 Volt, 35 Amp., 0.53 KVA

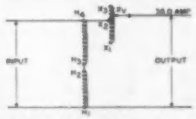


INPUT 240 Volt, 50/60 Cycle, 1 Phase
OUTPUT 15-0-15 Volt, 35 Amp., 0.53 KVA



INPUT 120 Volt, 50/60 Cycle, 1 Phase
OUTPUT 105-135 Volt, 35 Amp., 4.7 KVA

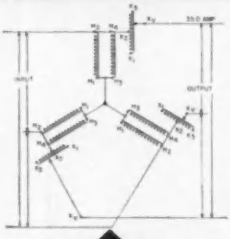
INPUT 107-137 Volt, 50/60 Cycle, 1 Phase
OUTPUT 120 Volt, 35 Amp., 4.2 KVA



INPUT 240 Volt, 50/60 Cycle, 1 Phase
OUTPUT 225-255 Volt, 35 Amp., 8.9 KVA

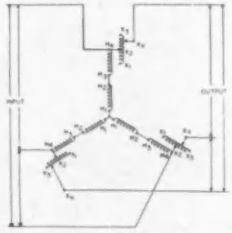
INPUT 226-256 Volt, 50/60 Cycle, 1 Phase
OUTPUT 240 Volt, 35 Amp., 8.4 KVA

THREE PHASE



INPUT 240 Volt, 60 Cycle, 3 Phase
OUTPUT 210-270 Volt, 35 Ampere, 16.4 KVA

INPUT 214-274 Volt, 60 Cycle, 3 Phase
OUTPUT 240 Volt, 35 Ampere, 14.6 KVA



INPUT 480 Volt, 60 Cycle, 3 Phase
OUTPUT 450-510 Volt, 35 Ampere, 31.0 KVA

INPUT 452-512 Volt, 60 Cycle, 3 Phase
OUTPUT 480 Volt, 35 Ampere, 29.1 KVA

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SERVO AMPLIFIER

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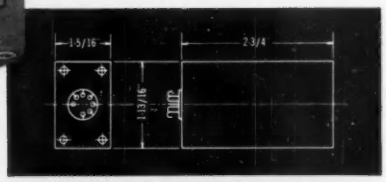
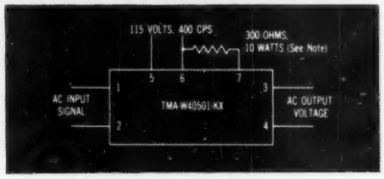
- TRANSISTOR-MAGNETIC
- HIGH GAIN
- ½ CYCLE RESPONSE
- MINIATURIZED
- —55°C to 100°C

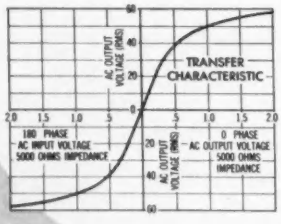
MODEL
TMA-W40501-KX





Note: Unit will be inoperative when external connection is open. Exact resistor value for other motors should be chosen so that the D.C. voltage across the resistor is approximately 18 volts.

Designed for service where available space is at a minimum. Features high gain, fast response and drift-free characteristics. Completely self-contained, unit requires no power supply, demodulation or preamplifier; a complete high performance servo loop is obtained without added amplifying elements. These characteristics are achieved by employment of a stabilized silicon transistor preamplifier with a high speed, fast response miniaturized magnetic amplifier output stage. For complete data, request Bulletin 100-106.



General Specifications:

Supply Voltage	115V
Supply Frequency	400 cps
Rated Max. Power Output	3.5 watts
Typical Motor Load	Bu. ORD MK 14 or Kearfott R119 Servomotor
Output Voltage	0-57.5 Volts
Load Impedance	940 ohms
Input Impedance	5000 ohms
Sensitivity	See Characteristic Curve
Zero Drift	Less than 1%
Weight	7¾ ounces

MAGNETIC AMPLIFIERS • INC

632 TINTON AVENUE, NEW YORK 55, N.Y.—CYpress 2-6610
West Coast Division
136 WASHINGTON ST., EL SEGUNDO, CAL.— EAstgate 2-2056

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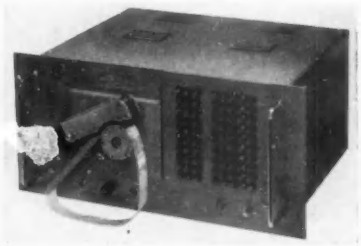
NEW PRODUCTS

0.65 in. in diam and 1⅛ in. long. Brushes are rated at 40 vdc at 20 ma, and can operate directly into most associated circuits. Total expected life exceeds 1,000 hrs under environmental conditions represented by MIL-D-5272A.—Instrument Development Laboratories, Inc., Attleboro, Mass.

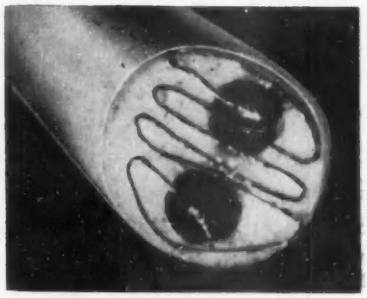
Circle No. 12 on reply card



TAPE READER

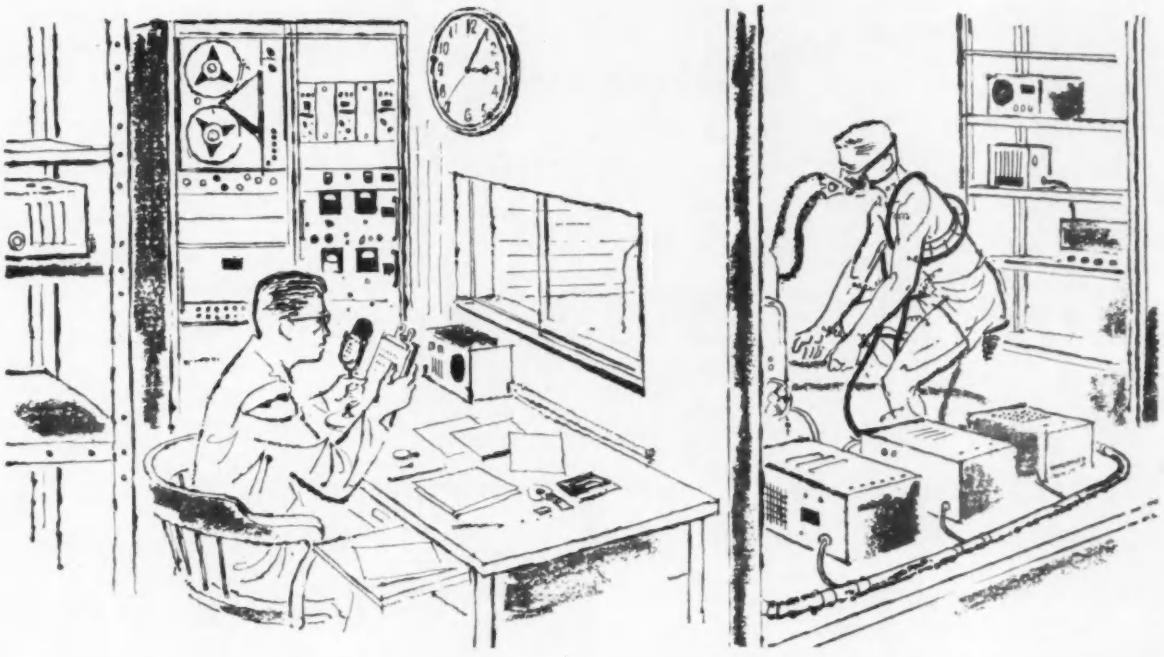
The new Tape-ard Reader will simultaneously read 10 transverse rows of eight holes each in a perforated tape, thus combining the advantages of both tape and card readers. The unit can supply 80 bits of information for each event without the use of memory circuits. Suitable for programming automatic production and test equipment, the reader accommodates standard 1-in. tapes with holes on ⅒-in. centers, and will operate in excess of 15 80-hole frames per sec.—California Technical Industries, Belmont, Calif.

Circle No. 13 on reply card



TINY PROBE

This miniaturized, high-temperature resistance thermometer probe has a 0.044-in. base and is believed to be the first to provide a flat grid temperature element wound on the end of a 1-millimeter tube. The photo, magnified many times, shows details of the platinum wire grid. All temperature-



PUTTING BODY RESPONSES ON TAPE SPEEDS RESEARCH IN HUMAN PHYSIOLOGY

Q: How do environmental conditions affect the total physiology of a human being?

Q: What are the effects of age, sex, health, etc., on work performance, and what range of variation can be expected within each group?

Q: How does the body regulate temperature and respiration under varying environmental conditions and exercises?

The answers to the questions posed above cannot be found in the literature. Why? Not too little data, but far too much . . . so scattered that it cannot be brought together for integration and analysis. Now, strides forward in the techniques of automatic data handling may help scientists provide the answers.

Consider the problem posed by the study of a man repeating a simple manual task. The force he exerts can be measured by placing him on a ballistic platform. But ten minutes of experiment might easily necessitate a full day of computation. Repeating the experiment in other environments multiplies the days of computation. To study the effect of fatigue on his performance means a full day of experiment in each environment . . . months of computation. A significantly large number of subjects assures valid conclusions, but means scores of man-years of mathematics. And integrating body temperature, heart rate, etc., into your results requires scores more.

The availability of large computers has now made such analysis conceivable. But only the development of magnetic tape data recording has made it feasible.

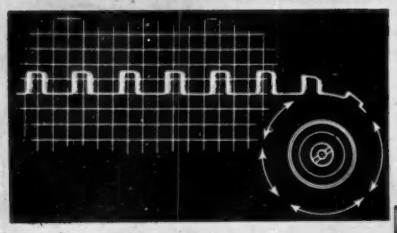
Magnetic tape is the vital link between experiment and computer. Accepting electrical signals from measuring instruments, it stores the information for long periods of time . . . plays it back in exactly the same form . . . the one language all electronic data analysis equipment understands. It further offers the facility of high data storage density. Far more data can be economically stored than a single typical experiment demands, and the surplus data used in future studies. Portability permits data recorded on the spot to be analyzed a continent away with no loss of time or accuracy.

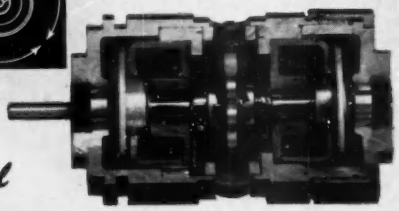
The techniques of magnetic tape data recording were first developed less than a decade ago by the Davies Laboratories Division to solve similar problems in the field of aircraft vibration analysis. The first systems specifically designed for physiological research have just recently been placed in operation. Designed for flexibility, they economically meet initial demands for data capacity, yet may be expanded at little expense to satisfy changing requirements. Up to thirty-six individual tracks of data can be simultaneously recorded . . . and interchangeable electronics permit recording each kind of data by the most desirable technique . . . Direct, FM, or PWM. Up to six recording and playback speeds can be chosen at the flip of a switch for data expansion or contraction. The same system will play back data to associated analysis equipment, or the reel can be shipped to remote analysis facilities.

Considerable information on magnetic tape data recording and how it might be best applied to your data recording, reduction, and analysis needs is provided in our Bulletin 1001, available on request to Minneapolis-Honeywell Regulator Company, Davies Laboratories Division, 10721 Hanna Street, Beltsville, Maryland. WEbster 5-2700

MINNEAPOLIS
Honeywell
DAVIES LABORATORIES DIV.

STEPPER MOTOR





PROVIDES

Bi-Directional

PROPORTIONAL SHAFT ROTATION FOR A GIVEN PULSED INPUT

MODEL SM-300-1

- Angular increment per pulse — 36°.
- Stepping rate — up to 15/second.
- Voltage requirement — 28 V. D.C.
- Duty cycle — $\left(\frac{\text{on time}}{\text{on time \& off time}}\right)$ 56% max.
- Weight — 8 oz.
- Shock — 15 G's for 11 milliseconds duration each way along three major axes.
- Reliability — shall not fail to convert more than one pulse in 1,000,000 into equivalent angular rotation.

OTHER MODELS AVAILABLE WITH VARIATIONS FROM THE ABOVE SM-300-1 SPECIFICATIONS.

The two rotary solenoids contained in each motor produce the incremental motion of the output shaft in either direction. Energizing either of these solenoids produces a combination of linear and rotational motion which moves a ratchet gear axially into engagement with its mating ratchet gear and thus imparts a constant amount of rotation to the output shaft. The detent roller assembly insures consant, reproducible angular shaft rotation increments in either direction and maintains the output-shaft position while the motor is at rest with the power off.

Stepper Motors are adaptable to routine jobs such as driving mechanical counters. They also find excellent use in positioning devices that will set up a controlling voltage and/or a phase shift such as potentiometers and autosyns. They are widely used as a positioner for guided missiles to adjust heading, fuel flow, altitude, and circuit sampling for telemetering purposes. In one adaptation as a heading controller, two Stepper Motors are used to position a differential autosyn in steps of either vernier degree or coarse degrees per input pulse, bi-directionally, through a suitable gear train.

Write for more details—available upon request.

STEPPER MOTORS CORPORATION

Subsidiary of California Eastern Aviation, Inc.

7444 West Wilson Avenue • Chicago 31, Illinois

NEW PRODUCTS

sensitive wires lie in a single plane, giving grid resistance values of from 12 to 16 ohms at room temperature. The probe is capable of operation over a range of 0 to 1,200 deg C. The double-bore tube offers porcelain protection for the lead wires.—Arthur C. Ruge Associates, Inc., Cambridge, Mass.

Circle No. 14 on reply card

FOR SHAFT POSITION

This highly accurate shaft position transmitter has infinite resolution and a null point at the center of rotation. Designated Model 85175S-5, it consists of a standard three-turn, slidewire Spiralpot potentiometer which has incorporated within its case fixed resistors wired in a bridge circuit. One leg of the bridge is shunted with the variable section, and output can be read on a sensitive light beam galvanometer. Linearity over plus or minus 360-deg rotation is about plus or minus 0.11 percent. Case measures 1.5 in. in diam by 1.5 in. long.—G. M. Giannini & Co., Inc., Pasadena, Calif.

Circle No. 15 on reply card

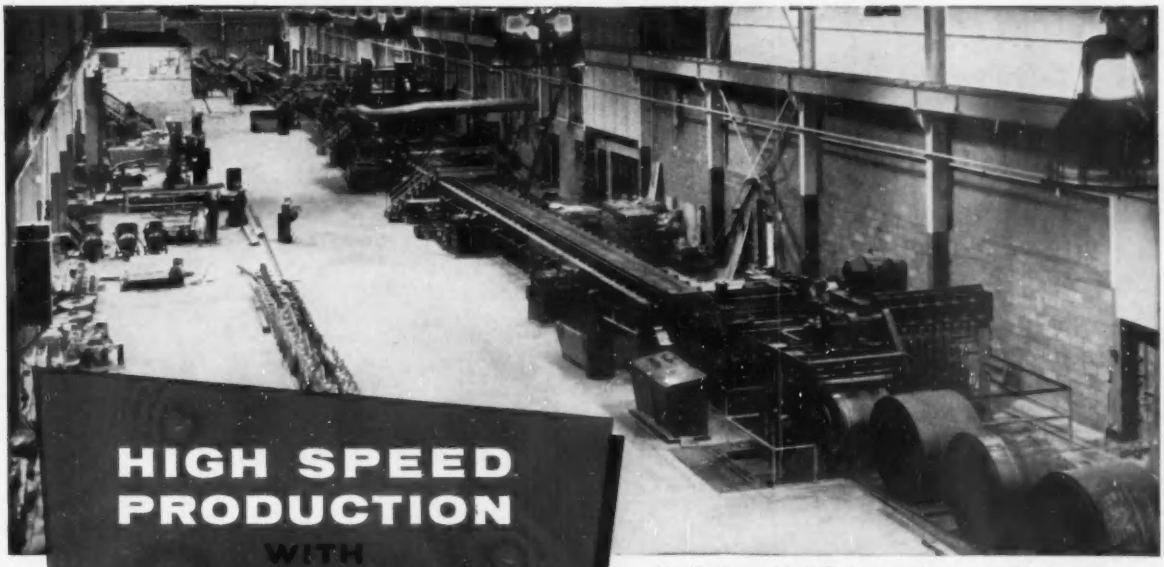
HIGH SENSITIVITY

Now in production, this company's newest infrared detector is said to be sensitive to 7 microns and to have a time constant of less than 1 microsec. It needs no cooling or bias voltage. Noise equivalent power is about 0.001 microwatt. — Radiation Electronics Corp., Skokie, Ill.

Circle No. 16 on reply card

DIAL THERMOMETERS

The new Palmer 3½-in. dial thermometer (Model 1035) fits all bimetallic wells. Its stem can be placed at any angle, and its case rotated to any position without affecting the accuracy of the reading. Features include a direct drive Bourdon coil, filled system, and



HIGH SPEED PRODUCTION WITH RELIANCE V★S DRIVES

Six Reliance V★S Drives make it possible to operate this complete line as if it were a single machine.

Carloads of pipe are pouring out of the new Edmonton, Alberta plant of Alberta Phoenix Tube & Pipe, Ltd. This $6.5 million installation is producing pipe at unprecedented rates.

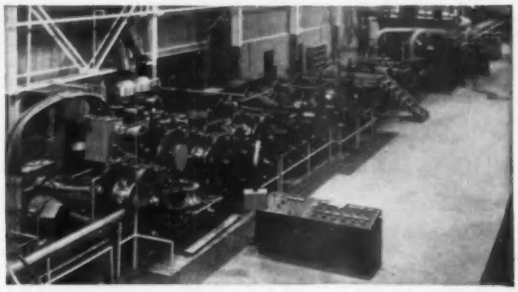
Volume pipe production requires something special in a drive system—one that furnishes precise speed control and instantaneous motor response. A wide stepless range of speeds is provided to handle various pipe diameters and lengths, and all sections of the line operate at the same relative speed.

A team of Reliance Application Engineers, working with the machinery builder, built this specialized drive. This team knows the processes of the steel industry and how to handle the problems involved. Engineering knowledge, backed by the quality of Reliance products, supplied this accurate, simple-to-operate, economical drive.

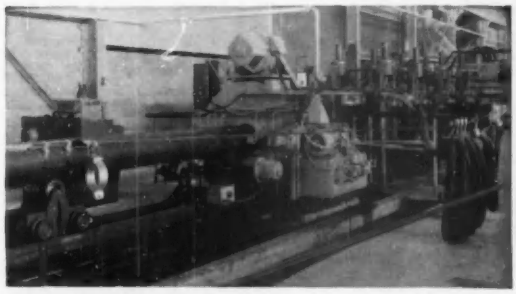
The Reliance Application Engineering Department builds drives for every industry. A team of engineers who are experts on your industry's operation, stand ready to engineer and build the drive for your particular needs.

If you would like more information on this installation, write for Bulletin L-2505.

L-1641



The welding section operator controls the speed of the entire line from this Reliance Pendent Station.



The Reliance V★S Drive on this flying cutoff automatically measures the pipe and controls the movement and speed of the carriage.

RELIANCE ELECTRIC AND ENGINEERING CO.

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Sales Offices and Distributors in Principal Cities

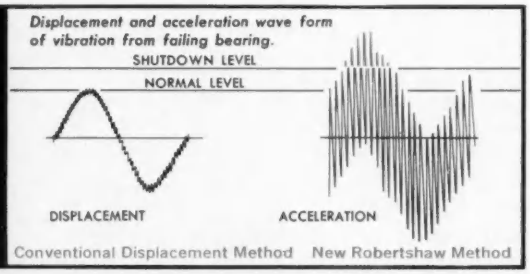
NEW PRINCIPLE STOPS COSTLY EQUIPMENT DAMAGE

before it can start!

ROBERTSHAW VIBRASWITCH®
MALFUNCTION DETECTOR

Responds to Peak Acceleration

DETECTS DAMAGING MALFUNCTIONS THAT CAUSE ACCELERATION TO EXCEED NORMAL LEVEL



ANTICIPATES trouble such as bearing failure, imbalance, broken blades, bent shafts or any malfunction causing vibration or roughness to increase. *ACTUATES* alarm or shutdown when acceleration exceeds normal level. *SENSES* all types of shock and vibration. *RESPONDS* only to harmful vibrations—can ignore start-ups and temporary disturbances normal to operation. *OFFERS* resistance to rain, dust, oil and explosions in a variety of housings.

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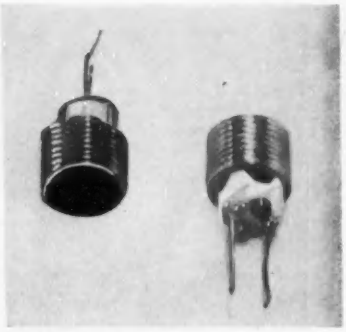
Robertshaw-Fulton
CONTROLS COMPANY

FIELDEN INSTRUMENT DIVISION
Dept. S, 2920 N. 4th St., Philadelphia 33, Pa.

NEW PRODUCTS

external calibration for zero setting.—Palmer Thermometers, Inc., Cincinnati, O.

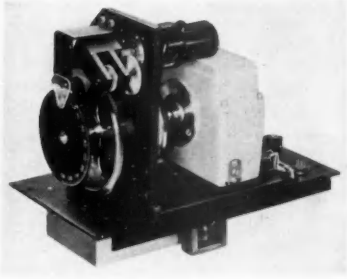
Circle No. 17 on reply card



EMBEDDED JUNCTIONS

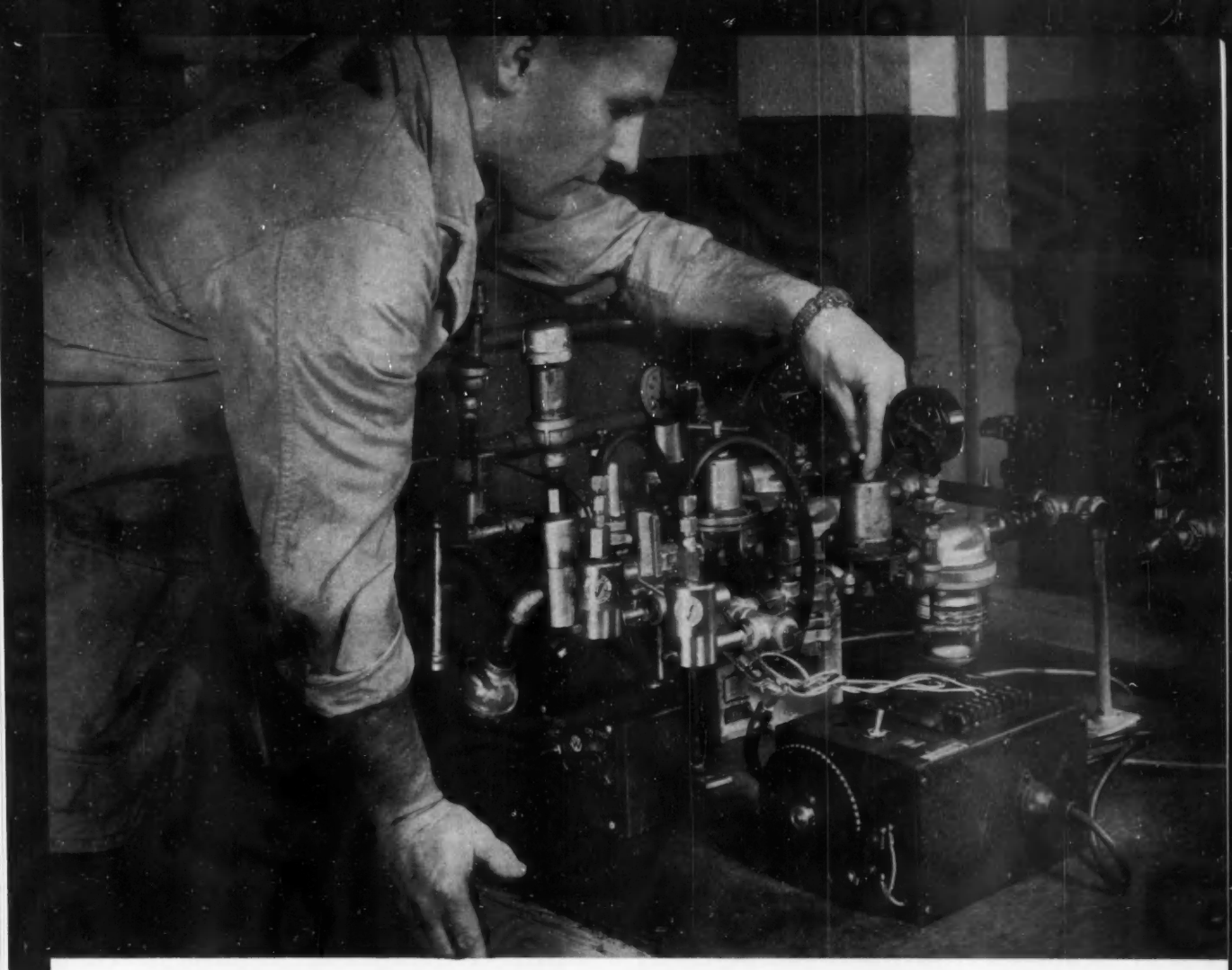
These Delta-Couples (miniature thermocouples) measure temperatures at precise in-wall locations. They are made by imbedding ribbon junctions, at selected depths, in ¼-in. threaded plugs of steel or aluminum. Features include small size, adequate response, minimum disturbance of heat flux, and simultaneous response with the wall material. Temperature ranges are 50 to 1,000 deg C in steel, and 50 deg C to the melting point in aluminum. —Detroit Controls Corp., Redwood City, Calif.

Circle No. 18 on reply card



SERVO ENCODER

The SL-1004, a packaged, servo-driven encoder, designed to digitalize ac input signals, operates directly from a 400-cps line and includes a miniaturized, high-gain transistor-magnetic servo amplifier and power supply. Output is binary decimal. The shaft is driven plus or minus 170 deg from null. Full-scale corresponds to 10-volts rms at 400 cps in phase with the line. Static error is 0.15 percent of full-scale. Typical applications in-



You can expect extremely long life from Skinner Solenoid Valves. Here's why...

In the lab shown above, dozens of Skinner valves are life-cycled 24 hours a day, 7 days a week, at speeds as high as 600 cycles per minute. It is here that we try out new designs, new materials, new construction methods. It is here that we test the stability of our welded joints . . . the resistance to burnout of our coils . . . the effectiveness of our positive spring returns . . . the better seal we obtain by eliminating packings. And it is here we find positive proof of Skinner valves getting over 20,000,000 cycles without leakage.

Service records of many millions of trouble-free cycles indicate that these constant laboratory tests are worthwhile and necessary to assure outstanding performance on critical applications.

For complete information on Skinner's line of 2-, 3- and 4-way valves, write us or contact a Skinner representative. Write Dept. 348.

Skinner Solenoid Valves are distributed nationally

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Flutter Effects of Wind Tunnel Model

are recorded on

TECHNICAL CHARTS

at Bell Aircraft Corp's. Research Laboratory

On this Bell-designed multi-channel digital recorder, strain data on wind tunnel models are recorded on a *Technical* strip chart at the analog recorder, converted to a binary code, and automatically typed out by an IBM Machine.

This is but one of many research and production applications at Bell in which *Technical* Charts are depended upon for trouble-free recording. The fact that Bell can order any of over 10,000 different circular and strip charts from one source is another reason why Bell buys from *Technical*.

Write for Bulletin 75-B on TECHNICAL'S Standard chart services . . . or specify your particular chart problem for Special service.

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NEW PRODUCTS

clude ground and flight instrumentation, analog translation to feed digital computers, input to card or tape systems, and laboratory demonstrations. — Industrial Controls Co., Lindenhurst, N. Y.

Circle No. 19 on reply card

LOW HYSTERESIS

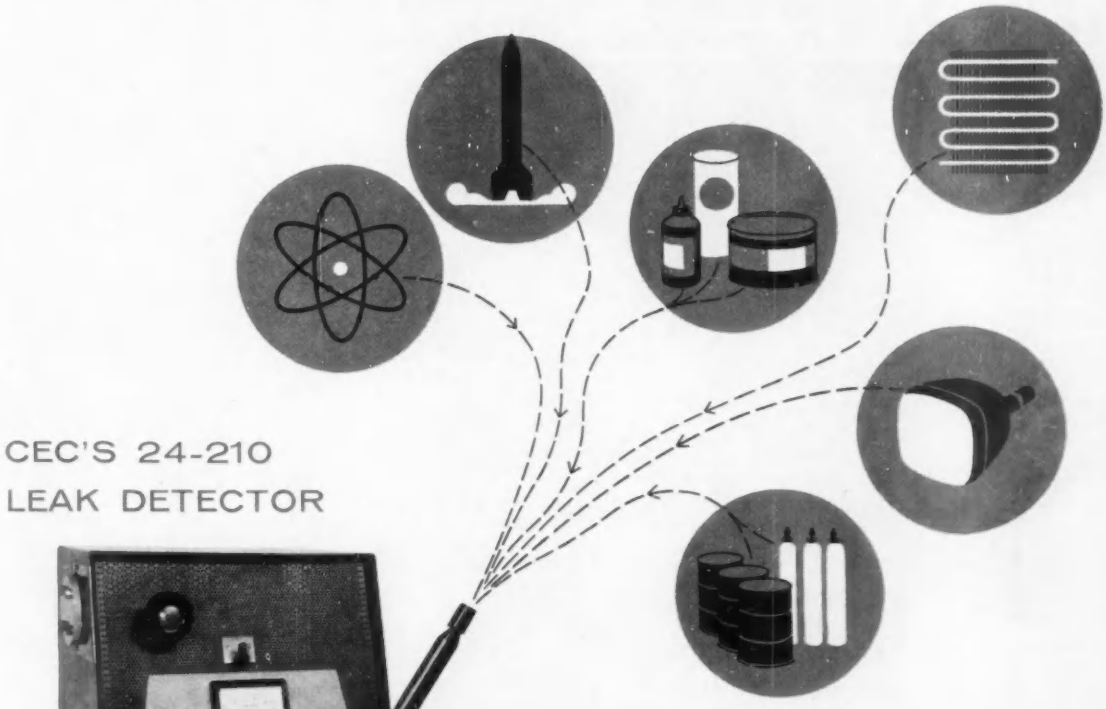
This accurate and versatile potentiometer pickoff accelerometer for automatic control and flight-test applications features dual or single pot and/or switch pickoffs and comes in a variety of g ranges. A torsion bar restraining mechanism gives very low hysteresis and long life. Air damping requires no heater over a wide range of temperatures. Accuracy is within plus or minus 1 percent for most ranges.— Pacific Scientific Co., Los Angeles, Calif.

Circle No. 20 on reply card

NULL VOLTAGE UNDER 10 MV

A new viscous-damped, high-output, low-null-voltage linear accelerometer has the following features: temperature range of minus 54 to plus 200 deg C; temperature effect less than 0.75 percent; threshold of 1/100,000 full-scale acceleration; linearity better than plus or minus 0.5 percent; hysteresis less than 0.15 percent; and vibration performance of 25 g's to 2,000

Easiest, most economical way to leak-test your product



CEC'S 24-210
LEAK DETECTOR

Unlimited applications in leak detection

Now you can test your product for vacuum seal, or locate leaks in any pressurized system with pinpoint precision and practical economy. CEC's 24-210 gives you highly sensitive leak detection and long, trouble-free service. Compact and highly simplified, this low-cost, mass-spectrometer-type instrument detects leaks so minute that 50 years would be required for 1 cc to escape. Easy, convenient operation requires no special training or experience. Just plug into a 115-volt, 60-cycle line. Find out how fast the CEC 24-210 Leak Detector pays for itself. For detailed information contact your nearby CEC field office or write for Bulletin CEC 1830-X24.

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You can't beat all-plastic Dekoron Poly-Cor for chemical resistance or for ease of installation. And now, the *new* Dekoron Instrument Tubing Harness adds yet another revolutionary feature—*fire resistance.*

For example, in the direct flame of a cutting torch, it lasted longer than any other multiple-tube harness. Use it in areas where flash fires are anticipated. And *new* Dekoron Instrument Tubing Harness is rugged, too. You can bury it and forget it.

You get all the advantages—chemical, impact and fire resistance—wrapped up in a single bundle with *new* Dekoron Instrument Tubing Harness. Remember, you can burn it . . . you can bang it . . . you can bury it. And you can *buy it now.*

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DEKORON PRODUCTS DIVISION
MANTUA, OHIO

NEW PRODUCTS

cps with less than 1-percent degradation in performance. Null voltages less than 10 mv are standard and outputs up to 12 volts can be obtained.—Physical Measurements Corp., Santa Monica, Calif.

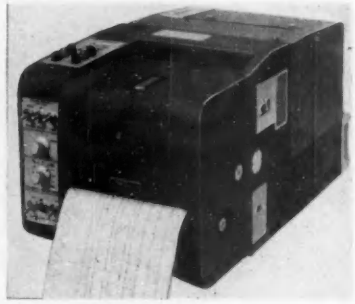
Circle No. **21** on reply card

INFORMATION DISPLAY INSTRUMENTS

QUICK RANGE CHANGE

Model 6705 strip-chart 24-point recorder features replaceable plug-in range clips and null-balance operation. Both chart speed and printing speed can be changed to suit application. Multiple alarm switches, set in a few seconds, are made selective by adding decks.—Weston Electrical Instrument Corp., Newark, N. J.

Circle No. **22** on reply card



DIRECT READOUT

Two new direct-reading oscillographs, Models 601 and 602, produce dry, self-developing records without chemicals within seconds after recording.

EDISON'S
RESISTANCE
TEMPERATURE
DETECTORS

wide range available for almost any type of use

MODEL 235N90-35
Designed for fast response and high resistance to the corrosive effects of rocket fuels used in guided missiles.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +200°C.
Exponential time constant in agitated waterbath 0.8 second. Maximum hydrostatic pressure on stem: 750 psi at 100°C.
Basic resistance at 0°C = 90 ohms.
Hermetically sealed.

MODEL 242P
This Detector can be operated in live steam or high temperature atmospheres up to 1300°F.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +750°C.
Maximum hydrostatic pressure on stem: 300 psi at 750°C.
Basic resistance at 0°C = 100 ohms.
Hermetically sealed.

MODEL 230N
A general purpose Detector for temperature measurement and control in industrial processes.
SPECIFICATIONS:
Stem-sensitive.
Basic resistance at 0°C = 120 ohms.
Hermetically sealed.

MODEL 166NC
Element is concentrated in tip for sensitivity to surface temperatures in motor bearings, etc.
SPECIFICATIONS:
Tip-sensitive.
Useable temperature range —70° to +300°C.
Basic resistance at 0°C = 120 ohms.

Rugged Edison RTD's are now available in 48 different types for use within indicating, recording, controlling and monitoring equipment. Adaptability of design and materials assures the construction of the best unit for each individual application.

Edison RTD's show marked advantages over conventional methods of resistance thermometry in any one of its many applications including: aircraft, missiles, missile fuels, pumps, motors, or anywhere temperature must be controlled and monitored. For one thing, they do not require signal amplification because they carry a potential of 1.5 volts sufficient to give an immediate indication on any type of instrumentation. For another, they give a time constant of less than ½ second because of their design (electrical bridge type) — a response time much faster than most industrial thermometer bulbs encountered.

The accuracy of metal RTD's is so great that the platinum RTD is the international standard between —190° C and +660° C. Edison RTD's tested years after manufacture show less than ± .05% change from the original calibration.

It will pay you to investigate the advantages of using Edison RTD's in your present or proposed temperature control work. Write for Brochure #3016.

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♦ FIBER CARTRIDGE
♦ POROUS METAL

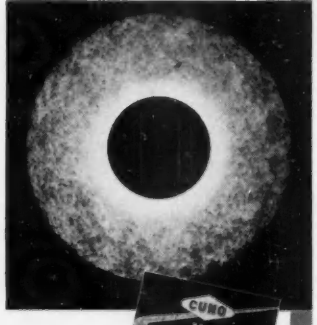
THE New WHITE CELLULOSE **MICRO-KLEAN®** FILTER CARTRIDGE

Where Filter Design Calls For—

5-MICRON FILTRATION . . . removes *all* particles down to this size *and* a large percentage of particles down to 1 micron or smaller.

COMPLETE SANITATION . . . for water, liquid food processing and other applications where *clarity, purity* and complete absence of any filter-imparted *taste* are essential.

EXCLUSIVE "GRADED DENSITY" construction makes entire depth of cartridge body available for micronic filtration . . . *doubles* cartridge life, cuts replacement costs *in half!*



COMPLETE DESIGN-ENGINEERING SERVICE

There is a Cuno Field Engineer located in your area. To help solve your design problems, this trained specialist offers you *more years of experience* in removing *more sizes of solids* from *more kinds of fluids.*

New DESIGN DATA . . . MICRO-KLEAN FILTER *combines fine filtration and high flow rates with important time- and space-saving advantages. Write now for your free copy of Catalog No. 53-100.*

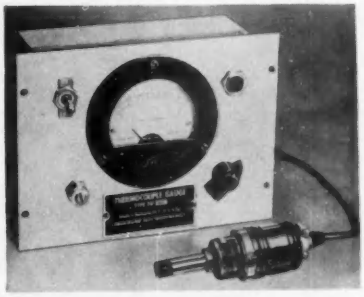
CUNO

CUNO ENGINEERING CORPORATION
2708 SOUTH VINE STREET, MERIDEN, CONN.
Filtration Engineers in Principal Cities

NEW PRODUCTS

Record width is 7 in. on the 601 and 12 in. on the 602. Features common to both models include: chart speeds from 0.0812 to 129.9 in. per sec; frequency range from dc to 3,000 cps; writing speed above 30,000 in. per sec maximum; and an 11-in. optical writing arm. Weights are 90 and 130 lb respectively. — Midwestern Instruments, Tulsa, Okla.

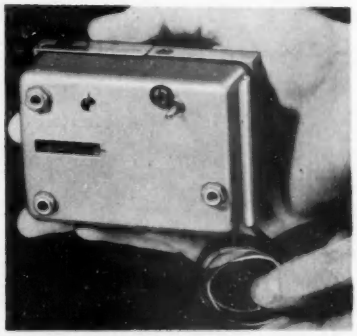
Circle No. 23 on reply card



T/C VACUUM GAGE

Designated the TG-025, this inexpensive thermocouple vacuum gage operates on two size-D flashlight batteries inside its housing. The single-station, panel-mounted unit has a nonlinear scale ranging from 0 to 1,000 microns Hg, with 0 to 60 microns extending over more than half of the entire scale. An all-metal sensing tube guards against exposure to atmospheric pressure. Low heater current reduces zero drift by decreasing the rate of thermal decomposition of organic vapors. — Consolidated Electrodynamics Corp., Rochester, N. Y.

Circle No. 24 on reply card



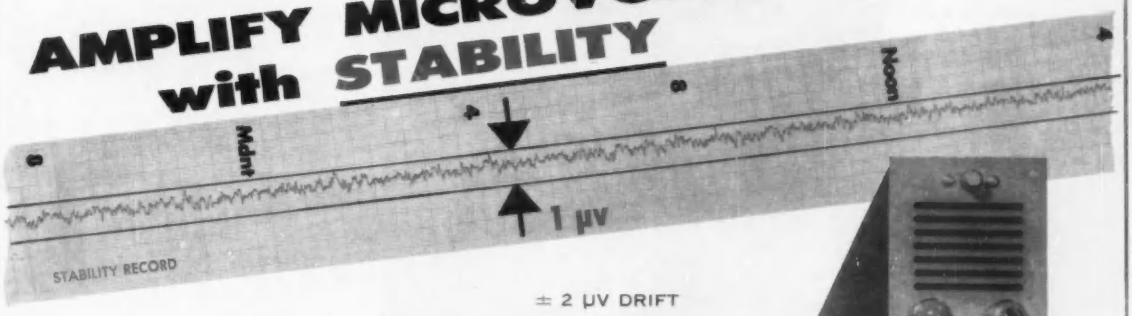
LINEAR INTEGRATOR

The Model 25 ball and disc linear integrator provides continuous integration and area of average computations,

KIN TEL
[KAY LAB]

FOR DRIFT-FREE DC INSTRUMENTATION

AMPLIFY MICROVOLTS with STABILITY



± 2 μV DRIFT

INTEGRAL POWER SUPPLY

HIGH OUTPUT LEVEL

EXTREMELY LOW NOISE

BROAD BANDWIDTH

10 ACCURATE GAIN RANGES

HIGH INPUT IMPEDANCE

The **KIN TEL** Model 111 amplifier provides maximum stability and the lowest drift of any commercially available broadband d-c amplifier. It is the end result of years of research in the field of chopper stabilized broadband d-c amplifiers. Thousands of **KIN TEL** amplifiers are in daily use. The Model 111 incorporates **KIN TEL's** proven chopper amplifier circuitry and provides ten extremely precise, feedback controlled gain ranges. Several feedback loops assure high accuracy, stability and uniform frequency response. The completely new and unique circuit provides rapid recovery from severe overloading and unsurpassed dynamic performance—unaffected by load or gain changes.

The Model 111 is available in a single-unit cabinet or in a six-unit rack-mountable module. The amplifiers are extremely compact; the six-unit module occupies only a 19-inch rack width.

APPLICATIONS: The Model 111 is ideal for permanent low level d-c instrumentation, telemetering, or as a strain gage amplifier, transducer amplifier, scope preamplifier, recorder driver amplifier, or general purpose laboratory amplifier.

SPECIFICATIONS

Gain	0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000
Gain Accuracy	± 1% DC to 2 KC
Input Impedance	100,000 Ω
Output Capability at DC	0 to ± 35 V where R_L > 1000 Ω 0 to ± 40 MA where R_L is 10 to 400 Ω
Output Impedance	Less than 1 Ω in series with 25 μh
Equivalent Input Drift	± 2 μv with regulated line
Equivalent Input Noise	0 to 3 cps, less than 5 μv peak to peak 0 to 750 cps, less than 5 μv RMS 0 to 50 kc, less than 12 μv RMS
Chopper Intermodulation	Less than 0.1%
Linearity	Better than 0.1% to 2 KC
Frequency Response	± 3% (0.3 db) DC to 10 KC, less than 3 db down at 40 KC

Power Requirements:	
Amplifier	117 V—60 cycles—70 VA
Cabinet	117 V—60 cycles—15 VA
6 Unit Rack Adaptor	117 V—60 cycles—45 VA
Dimensions: Amplifier Unit	2⅞" wide, 7⅞" high, 14¾" deep
Rack Adaptor for 6 Units	19" wide, 8¾" high, 18¼" deep
Net Weight—Amplifier	11 pounds
PRICE: Amplifier Unit	$550.00
19-inch Rack Adaptor for 6 amplifier (with fans and connectors)	200.00
Cabinet for single amplifier (with fan and connector) is available.	

...the Standard in chopper-stabilized instruments

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[KAY LAB]
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WITH CHOPPER AMPLIFIERS

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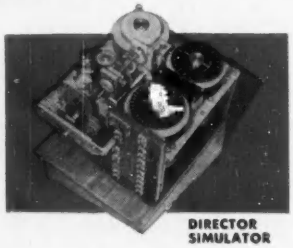
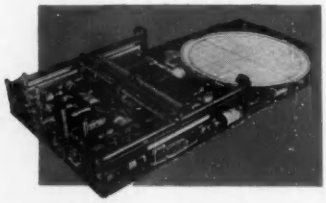
Daystrom Instrument has proven its RELIABILITY in achieving high quality, high volume production of assemblies and systems ranging in size from the sub-miniature to the massive. Our supporting engineers enable us to do the complete job from design through finished product.

Our production includes fire control systems, communication systems, test equipment, attack directors, underwater ordnance, power supplies, electronic chassis, radar, gear assemblies, aircraft instrumentation and a host of other products.

Let Daystrom Instrument assist you in meeting your product needs. One of our sales engineers is ready to discuss our qualifications with you. Write us, and he will call at your convenience.



DIRECTOR SIMULATOR



PILOT'S DEAD RECKONING INDICATOR

JUST OFF THE PRESS! Our New Facilities Brochure. Write for it!

DAYSTROM INSTRUMENT
Archbald, Pennsylvania
Division of Daystrom Inc.

NEW PRODUCTS

and gives a direct or remote reading. It can be used wherever the variable to be integrated is presented as a shaft position or displacement. Kits are available for adapting the device to a strip chart recorder. — Librascope, Inc., Glendale, Calif.

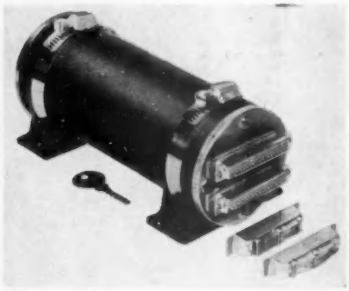
Circle No. 25 on reply card

CONTROL DEVICES

RUGGED COMPARATOR

This "Pressure Comparator" relates an unknown pneumatic signal to a fixed reference pressure. When the two pressures reach an equilibrium, an electrical contact is opened. Leads from the comparator may be used to indicate a zero differential pressure. The unit features a service life of at least 500,000 cycles.—Fischer & Porter Co., Hatboro, Pa.

Circle No. 26 on reply card

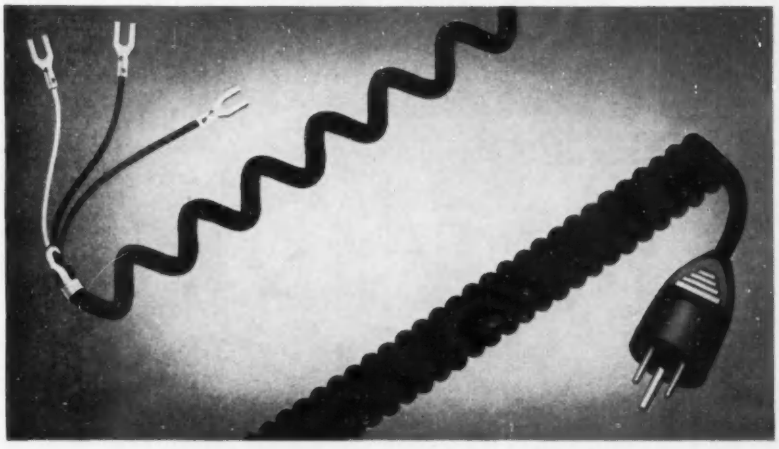


SAMPLING SWITCH

A cylindrical, pressure-sealed container in this multichannel missile telemetering sampling switch allows operations at altitudes up to 200,000 ft and in temperatures from plus 125 to minus 65 deg C. Models are available with from one to five poles, with up to

Specify CL COILED CORDS

...add important convenience and safety features to your equipment!



Cords Limited COILED CORDS are engineered for specific application!

Coiled Cords, first choice in the communications industry, find numerous important applications in other fields! In addition to user convenience, Cords Ltd. Coiled Cords provide a safety factor preventing costly industrial accidents. Maintenance-wise, Coiled Cords give much longer service than straight cords by eliminating common abuses that shorten serviceability.

Product Data: A leader in the development of Coiled Cords, Cords Limited is a major supplier of this product to the telephone and communication industries. Coiled Cords are engineered for specific applications. Special oil, acid and moisture resistant properties of the jackets protect the product under unusual conditions. The most modern molding facilities for plug and conductor termination are available at Cords Limited to serve your needs quickly and economically!

***WRITE TODAY* for complete details... your quotation requests will receive immediate attention!**

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ESSEX WIRE CORPORATION
DeKalb, Illinois

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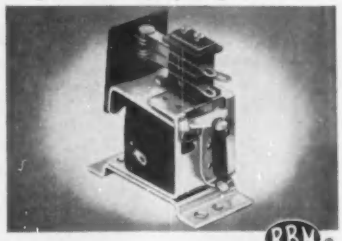
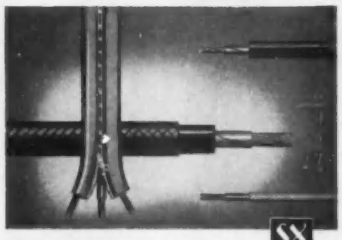


GENERAL PURPOSE RELAYS

A.C. or D.C. General Purpose Multipole relays. For circuit switching of electrical interlocking remote control devices. Features special cross-bar contacts for low-voltage, low current circuits or button type contacts for power switching circuits. Request Bulletin No. 1060.

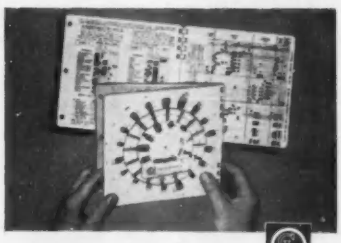
R-B-M "Control" Division
Logansport, Indiana



WIRE AND CABLE

A full "Extra Test®" line of lead, appliance, automotive and refrigeration wires, plus submersible pump cable and 200° C. Sil-X® insulations are examples of the versatility of "Essex Engineering".

Wire and Cable Division
Fort Wayne, Indiana



CORD SET DESIGN AID

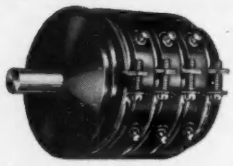
The CORDINATOR®, a time-saving engineering tool, features simplified charts showing approved wire by product types. Dial side permits visual fabrication of cord sets and power supply cords. All components standard approved... minimizing cost... assuring scheduled delivery. Write for your free CORDINATOR.

Cords Limited Division
DeKalb, Illinois

ESSEX WIRE CORPORATION

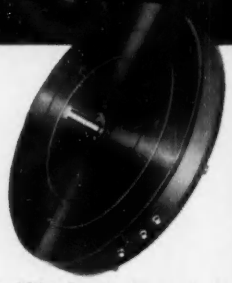
BIG PLUS in PRECISION POTS

RL-270A-1⅛ Precision Potentiometer . . . one of five sizes from 1¼" to 5" diameter. Non-metallic housing has high dimensional stability, withstands −70F to +300F.

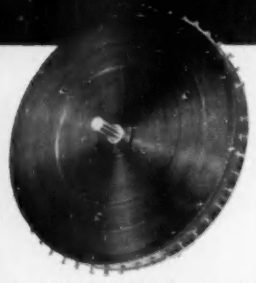


RL-270B-2 shows ganging which is available on all RL-270B models. Gamewell design requires only ⅜" per section, and external clamps provide unlimited phasing.

Gamewell *Blue Line* RL-270 A&B SERIES

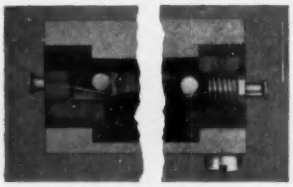


RL-270A-5 is the largest in the *Blue Line* series. As with others, it is usually supplied with 3-hole mounting. Servo and threaded-bushing type mountings are available. Also many special features . . . send us your requirements.

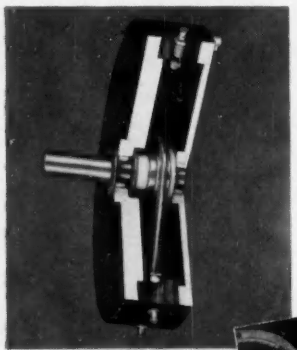


Special RL-270A-5 with 48 taps, shows maximum number. Allows 47 equal resistance sections, while maintaining guaranteed linearity of ±0.1%. Total resistance of 500,000 ohms, resolution of 0.0075%.

That Extra Margin of Reliability . . .



Exclusive Gamewell Terminal, Tap and Wiper Design



RL-270A and B Series available in many special variations. Write for catalog and specifications and prices on your specific requirements.

RL-270A Blue Line series offers these exclusive advantages:

- Proven and guaranteed linearity affords extreme accuracy, ±0.1 is best standard available.
- Terminal and Tap Design* uses positive precious-metal spring contacts with unit pressure over 10,000 psi. Assures permanent low-resistance contact without linearity distortion at taps.
- Shaft and Wiper Assembly* uses contoured slip-ring surface plated with noble metal, operating with noble metal brushes. Has excellent insulation to ground, high temperature resistance and zero moisture absorption.

THE GAMEWELL COMPANY
Newton Upper Falls 64, Mass.

GAMEWELL®

PRECISION POTENTIOMETER DIVISION

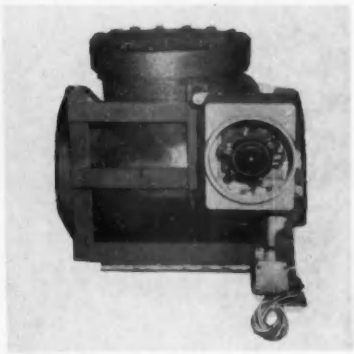
GA7 2

*Pat. applied for

NEW PRODUCTS

60 contacts per pole. Sampling speeds range from 0.5 to 30 rps. Motor drives include 6-, 12-, and 27.5-vdc motors, governed or ungoverned, 60-cps single-phase motors, and 400-cps single- or three-phase motors. The governed-dc units have a speed regulation of plus or minus 3 percent. All units will provide continuous operation for 100 to 1,000 hrs, depending on sampling speed, environmental conditions, and quality of the switching required.—Applied Science Corp. of Princeton, Princeton, N. J.

Circle No. 27 on reply card



PUMP CONTROL

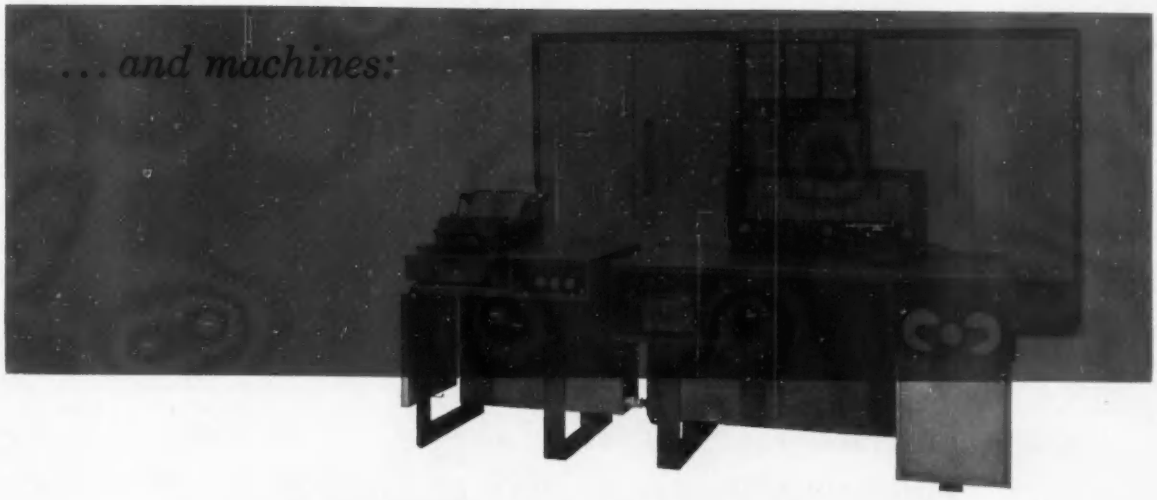
The Flow Actuated Control above represents a simple positive method for controlling a number of motor-driven pumps that supply a single product. There are no differential pressure switches or electric components, and pump motors are started sequentially as demand for product increases. The shaft of a large check valve extends through the valve body, and a circular dial is affixed to the end. A number of mercury switches, mounted radially on the dial, open or close motor circuits as product flow alters position of the check valve. Design permits working pressures to 175 lb.—Flow-Actuated Control Co., Inc., Englewood, N. J.

Circle No. 28 on reply card

POWER SUPPLIES

STANDBY BATTERIES

Model 102, a 24-30-vdc power supply which powers fire alarm and water deluge systems in several major oil refineries, uses Edison nickel-iron-



ElectroData attracts dynamic men through the fascination of wonder-working machines; holds them with the satisfaction of creative achievement; rewards them with ideal surroundings, a stimulating work atmosphere, and salaries commensurate with growth. As a pioneer and vital force in the fast-growing electronic data processing field, ElectroData offers a solid future to qualified electronic engineers. If this appeals to you, write: Professional Employment Manager, ElectroData, 460 Sierra Madre Villa, Pasadena, California.

ElectroData — Division of Burroughs Corporation

MINIATURE CONTROL COMPONENTS

. . a WRIGHT specialty

SIZE 9 SERVO MOTOR TACHOMETER GENERATOR

Diameter: 7/8 inch
Input: 26V-400 cy.
Speed: 9500 RPM
Torque Rating: 0.25 oz.-inch
Generator Output: .33 V/1000 RPM

This two bearing motor-generator set illustrates Wright's exceptional capability for production of special small precision components and assemblies. You are invited to consult us on your next requirements for . . .

A. C. and D. C. Motors · Servo Tach Units
Synchros In All Categories
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And Related Components and Assemblies

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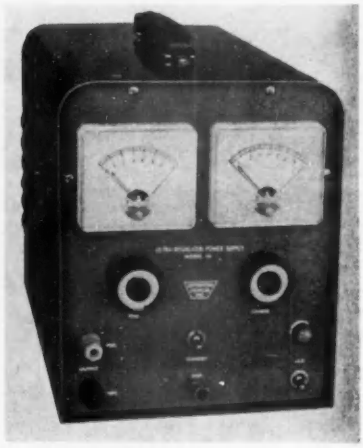
NEW PRODUCTS

alkaline storage batteries to provide continuous direct current in the event of an ac line shutdown. The batteries are charged in the standby condition and automatically transferred to the dc line when required. Rugged relay and meters are hermetically sealed to assure safe and reliable operation. A manual voltage control adjusts the dc line voltage and the charging current. To facilitate servicing, fuse posts and pilot lights are mounted on the front panel.—Earl Control Co., Burbank, Calif.

Circle No. 29 on reply card



USES ULTRASONICS

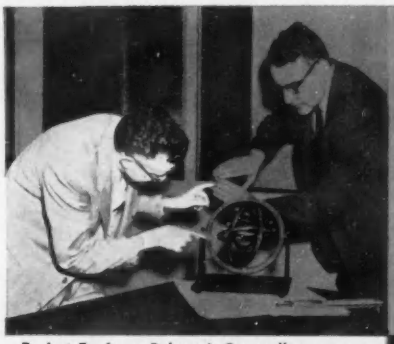
This new low-voltage dc power supply uses an ultrasonic carrier system for optimum performance consistent with light weight and small size. A number of feedback loops and corrective networks make output voltage virtually independent of line and load fluctuations. Negative voltage feedback provides for low drift, low noise, and low output impedance. Unit weighs only 23 lb and draws just 70 watts from the ac line at full output.—Optimized Devices, Inc., White Plains, N. Y.

Circle No. 30 on reply card

FINAL CONTROL ELEMENTS

RUGGED SOLENOIDS

A new line of ¼-in., four-way, foot-mounted control valves, said to be compact, fast, dependable, and inexpensive, is designed for control of



Project Engineer Robert J. Cantwell uses a system of gimbals to describe navigational problem in the analysis of a new system design.

Development Engineer J. Robert Holmes computes, with other systems reliability analysts, the operational worth of a bombing system.

Staff Engineer William Howard reviews gearing accuracy requirements of test equipment with electronic circuit designers.

You'll find a new challenge DEVELOPING airborne computers at

IBM Owego

Circuit Development Group Leader Ralph Wolcott considers future changes in computer output unit for bombing-navigational systems.

The design and development of BRANE (Bombing RAdar Navigation Equipment), now being installed in B-52 aircraft, offer stimulating new challenges to creative engineers at IBM Owego.

Projects currently in process include: Inertial guidance... display equipment ... radar data presentation ... digital and analog systems ... transistor circuit packaging ... test equipment ... installation.

If you are an electrical or mechanical engineer, a mathematician or a physicist —and want to do development work— you owe it to yourself to investigate the exciting possibilities that airborne computers offer you at IBM Owego.

Development Engineer John Walsh discusses the use of a recording storage tube at IBM's Airborne Computer Laboratories, Owego, N. Y.

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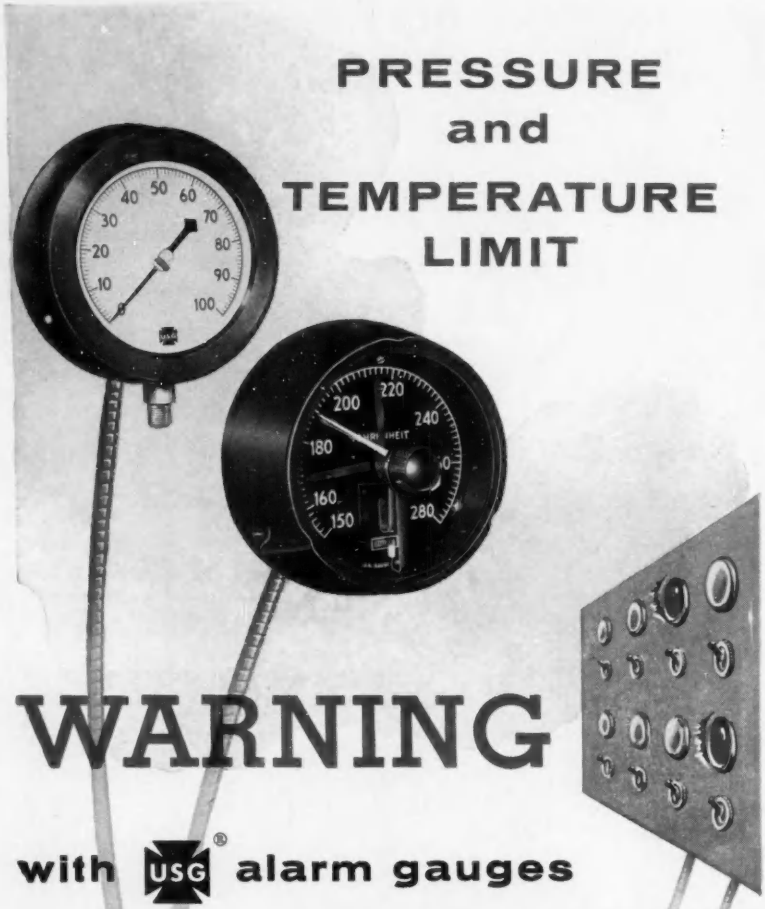

PRESSURE
and
TEMPERATURE
LIMIT

WARNING

with USG® alarm gauges
and thermometers

These instruments provide a warning signal when temperature or pressure in a process rises or falls beyond predetermined danger limits.

Limit contacts are adjustable over the entire range with a "gap" as narrow as 2%. Suitable for lights, bells, buzzers or other signaling equipment requiring 0.1 amps or less. For larger alarm or relief devices, external relays can be furnished to increase rating to 6 amps.

Instruments may also be used as limit controls and as on-off controls when used in conjunction with lock-in relays and suitable delay tubes.

Available in cast iron or phenolic turret case in 12 pressure dial graduations from 0-30 lbs. to 0-10,000 lbs. Vacuum ranges 0-30". 5 compound dial graduations from 30"-30 lbs. to 30"-300 lbs. Thermometers available in all standard mercury, vapor and gas ranges with phenolic case only.

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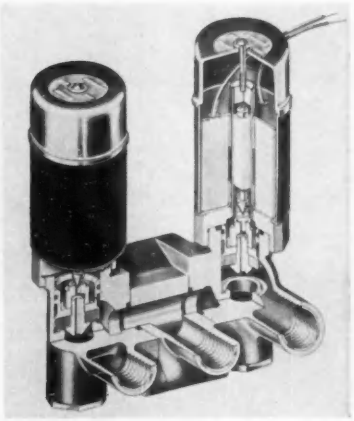
MORE THAN 50,000 TYPES OF GAUGES • SUPERGAUGES • SOLID FRONT GAUGES • RECEIVER GAUGES • TEST GAUGES • RECORDERS • CONTROLLERS • TRANSMITTERS • PSYCHROMETERS • AVIATION INSTRUMENTS

NEW PRODUCTS

small devices. Available in single- and double-solenoid types, the valves feature aluminum bodies, end caps, spacers and pistons. The solenoid coils, encased in molded epoxy resin, are guaranteed against burnout for the life of the valve. Manufacturer claims a service life of 25 million cycles.—Valvair Corp., Akron, O.

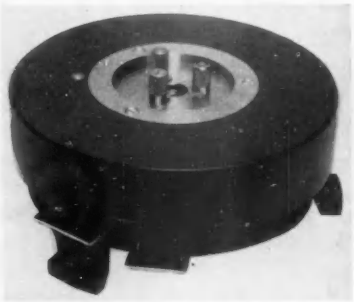
Circle No. 31 on reply card



THREE-WAY DUPLEX

This new double-solenoid valve provides unusual flexibility for three-way flow-control applications involving mixing, divided flow, and cylinder control. The bubble-tight valve may be used at pressures of from 5 to 1,000 psi with both pistons normally closed, and at 5 to 500 psi with either or both pistons normally open. It is available in ½-in. and ¾-in. pipe sizes, and features replaceable discs, pilot assemblies, and piston rings.—Atkomatic Valve Co., Indianapolis, Ind.

Circle No. 32 on reply card



PRECISE POSITIONING

This new angular divider will position a synchro shaft with less than 15 sec error and will rotate the synchro in

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(100) ALL-TRANSISTOR AMPLIFIER. Beckman Instruments, Inc. Bulletin 3003, 4 pp. Describes Beckman's all-transistor, high-gain dc amplifier. Block diagrams and photos illustrate operating principles, design features, and typical applications. Last page covers complete specifications.

(101) VARIABLE TRANSFORMER. The Superior Electric Co. Bulletin SE-L3578, 4 pp. Presents illustrations, outline drawings, and technical rating data on a new Powerstat variable transformer, Type LW136. Covers a single-phase model and a stacked unit for three-phase operation.

(102) DIGITAL AND ANALOG INSTRUMENTATION. Berkeley Div., Beckman Instruments, Inc. Catalog C-704. This short-form catalog describes 17 new instruments, including a number of the company's Eput meters, expanded scale volt- and frequency-meters, and resistance bridges. Brief specifications and prices are presented in separate tables.

(103) CONTROLLED-VOLUME PUMPS. Milton Roy Co. Bulletin No. 553-1, 32 pp. Contains complete specifications and latest design features on a complete line of motor-driven controlled-volume pumps. A selection data guide covers methods for calculating discharge pressure and suction head. Four pages of materials-selection charts show the relative merits of several different pump materials in handling a variety of chemical solutions.

(104) FOR MEASURING pH. Beckman Instruments, Inc. Bulletin 86-5, 13 pp. Bulletin 85L, one of several of this package, is made up in simplified chart form, completely indexed and illustrated. It is designed to guide users in selecting the correct pH electrodes for use with laboratory and portable pH meters. Other bulletins carry information on several of the company's meters, including an automatic unit and a laboratory standard.

(105) SERVOMOTOR–RATE GENERATOR. Helipot Corp. Data sheet 872, 2 pp. Complete specifications, characteristics, cutaway view, and schematic tell the control systems engineer about the company's new size 11, 115-volt, 400-cps servomotor-rate generator.

(106) PRECISION POTENTIOMETER. DeJur-Amsco Corp. Catalog sheet, 2 pp. Describes a number of special features that have been incorporated in a new 2-in., high resolution precision pot. Photos and dimensional drawings are included along with a list of general specifications.

(107) FULL-FLOW BALL VALVES. Chemtrol Corp. Illustrated data sheet. Contains an exterior picture of a new full-flow plastic ball valve, plus a cutaway illustration showing the internal construction and design. Also includes a complete listing of design dimensions.

(108) TANTALUM WIRE CAPACITORS. Ohmite Mfg. Co. Bulletin 148B, 8 pp. Describes two new tantalum wire electrolytic capacitors said to be the smallest units of their type available. It also reviews the complete line of these "Tan-O-Mite" units, gives maximum capacities and voltages for each of six case sizes, and lists the stock values immediately available.

(109) MEASURES VISCOSITY. Fischer & Porter Co. Catalog 15A 100, 4 pp. Covers the equipment used in the FP Viscorator, a temperature-compensated, automatic sampling instrument for measuring viscosity continuously to a base or reference temperature. Cutaway isometric explains the operation of the transmitting unit, and a viscosity-temperature chart illustrates temperature-compensation.

(110) AIR VELOCITIES. Illinois Test-

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ing Laboratories, Inc. Bulletin 2448, 8 pp. Contains some descriptive information on the company's velometers. Various jets and accessories are described, and applications discussed. Also includes prices.

(111) PRESSURE PICKUP. Consolidated Electrodynamics Corp. Bulletin 1568A, 2 pp. Illustrates and describes the Type 4-316 pressure pickup which, according to the manufacturer, is the first one capable of operating continuously at 600 deg F. Electrical features, specifications, and dimensional drawings included.

(112) VOLTAGE ADJUSTORS. Acme Electric Corp. Bulletin VA-312, 4 pp. Emphasizes the importance of constant voltage in electrical systems, and covers briefly the problem of voltage drop and fluctuations. Two large tables of specifications and dimensions presented.

(113) OPTICAL AIDS. Edmund Scientific Co. Catalog, 72 pp. Well illustrated this catalog lists over 1,000 items of optical equipment. Lenses, prisms, wedges of all descriptions, and many other instruments and components included.

(114) HIGH-VACUUM EQUIPMENT. Consolidated Electrodynamics Corp. Bulletin 1-1, 24 pp. Actually a general catalog, this bulletin deals with CEC's high-vacuum equipment for laboratory and industrial use. Covers pumps, valves, baffles, traps, gages, and leak detectors, vacuum metalizing equipment, high vacuum furnaces, and other high-vacuum processing units.

(115) SENSITIVE ANALYZER. National Instrument Laboratories, Inc. Bulletin 175, 4 pp. Describes the operating principles of the company's Sonic Gas Analyzer for gas and vapor chromatography and selective absorption. Photo and schematic accompany this description. Log-log graph shows sensitivity of the unit to gases in helium carrier.

(116) MAGNETIC COMPONENTS. Avion Div., ACF Industries, Inc. Bulletin, 2 pp. Covers some of the characteristics and advantages of the manufacturer's special magnetics, components designed to meet unusual performance requirements and available on short notice.

(117) LINEAR ACCELEROMETER. B & F Instruments, Inc. Bulletin LF-MF-6-57, 2 pp. Gives detailed and general specifications on a completely redesigned line of linear accelerometers. Applications are discussed and both low- and medium-frequency models are illustrated.

(118) RELAY FACT FILE. Ebert Electronics Corp. Catalog 157. Contains technical information on mercury plunger relays and related products. It includes load ratings and contact data, coil characteristics, mounting dimensions, diagrams and illustrations, and general information of particular interest to the engineer.

(119) ROTARY KILN OPERATION. Leeds & Northrup Co. Process data sheet 705(1), 4 pp. Explains the advantages of using the measurement of the oxygen concentration in rotary kiln exit gases as an index of performance, and describes how L&N equipment is applied in such cases. Photos and diagrams show the details of the system and its installation.

(120) PUMPS AND VALVES. Hills-McCanna Co. Catalog No. 800, 12 pp. Titled "Positive Flow Control", this booklet covers proportioning pumps and diaphragm valves. It describes in detail four basic pump models for accurate and positive proportioning of flow in the range of 0.730 gph. Diaphragm valves for positive closure are described and their exclusive features pointed out.

(121) VARIABLE TRANSFORMERS. The Superior Electric Co. Bulletin P257H, 28 pp. Offers features, ratings, and complete data on a new standard line of Powerstat variable transformers for high-frequency applications. Covers over 35 types of miniaturized manual and motor driven units.

(122) PRESSURE MEASURING. Fischer & Porter Co. Catalog 11-102, 12 pp. Describes the Press-I-Cell, an instrument for the precise measurement of absolute, gage, or differential pressures. Covers the various transmission means, optional alarms, and special explosion-proof and portable models.

(123) INSTRUMENTATION NEWS. Beckman Instruments, Inc. Bulletin No 19, 12 pp. Features news and technical stories on laboratory instrumentation. Describes two new products and three new accessories, and contains a new-literature listing on the back cover. Three pages of infrared notes.

(124) PNEUMATIC CONTROLS. Moore Products Co. Bulletin 5013, 18 pp. Describes the company's complete line of Nullmatic controllers, control stations, derivitive units, and pneumatic relays. Detailed schematic drawings, in color, illustrate the pneumatic force balance operation, and the various modes of control. Line drawings of typical control circuits also presented.

(125) PAPER-FINISHING CONTROLS. Westinghouse Electric Corp. Bulletin B-4038-A, 16 pp. Discusses the advantages and special features of Westinghouse supercalender drives, winder drives, coordinated drives, and AV packaged drives, covers magnetic-amplifier regulator controls for use with each type of drive. Photos illustrate actual installations.

(126) INDICATING CONTROLS. Tipp-Tronic, Inc. Catalog AC-2, 16 pp. Limit and cycling control devices are described along with certain accessory equipment. Photos, circuit diagrams, and specifications cover the technical information. Prices are included.

(127) DESIGNER'S GUIDE. Trio Laboratories, Inc. Catalog, 36 pp. Contains

photos, outline drawings, descriptions, theory of operation, mounting details, and complete specifications on the company's entire line of panel-mounting, miniature electronic components. A "Designer's Guide" section covers selection and application of equipment for built-in system components.

(128) COPPER-CLAD LAMINATE. Westinghouse Electric Corp. Bulletin B-6577, 8 pp. Photos, diagrams, and text discuss what printed circuits are, the advantages to be gained from their use, and the construction and properties of Micarta plastic laminate. Data sheet covers the types available.

(129) LONG-LIFE CAPACITORS. Industrial Condenser Corp. Catalog 1165, 12 pp. Presents data not previously available on electrolytic capacitors, and describes a new capacitor that eliminates problems such as short operating life, excessive leakage current, rapid shelf aging.

(130) HYDRAULIC POWER UNITS. Oil-Dyne Inc. Catalog, 52 pp. Contains complete technical data and specifications on 2,240 types and models of Oil-Dyne pumps, single and duplex pressure switches, hydraulic cylinders, and a full line of accessories.

(131) ACCURATE FLOWMETER. Leeds & Northrup Co. Data Sheet 463-170, 4 pp. Schematically illustrates the operation of the L&N Centrimax Flowmeter for accurate flow recording. Also explains that additional equipment is available for totalizing integrated flow, rate of flow, or both.

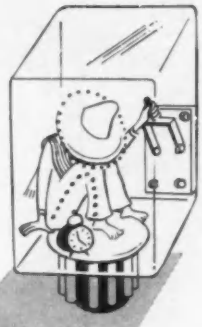
(132) "ELECTRIONIC" CONTROLS. Barber-Colman Co. Bulletin F 2287-4, 4 pp. Discusses the application of this manufacturer's new Electrionic temperature controls for the heating, ventilating, and air-conditioning field. Explains all the features, functions, and advantages of this type of system. Components and accessories are illustrated.

(133) PARTS FOR BREADBOARDING. Beckman/Helipot Corp. Catalog 575, 24 pp. Contains photos, drawings, and detailed descriptions of breadboard parts for use in electromechanical experimental and developmental work. Parts are cross-indexed for easy reference and a price list is included with each catalog.

(134) PRESSURE GAGES. Helicoid Gage Div., American Chain & Cable Co., Inc. Catalog G-52, 32 pp. Graphically describes a complete line of pressure gages for industrial, processing, and chemical applications. Covers operating principles, types of systems, adjustments, and specifications. Accessories also included.

(135) ANALOG COMPUTERS. GPS Instrument Co., Inc. Booklet, 8 pp. "High-Speed Analog Computers" answers questions on various types of computers and compares the virtues and limitations of high-speed analog units with those of real-time computers. Also describes how the GPS computers provide repeatability of solution and solution readout.

(136) MOTORS, FANS, AND BLOWERS. Ashland Electric Products, Inc. Catalog 83, 14 pp. Offers full details, physical specifications, and electrical characteristics of a complete line of synchronous, torque, induction, and gear motors, centrifugal blowers, and axial fans.



PERSPICUOUS SWITCH

Is it enough that a relay works? Not since we discovered the omission of a singularly vital instituent. To be a first-rate success today, a relay must *reveal* what it is doing every minute. With this in mind Sigma has developed a Radically New type of fully enclosed relay (see above) in which all moving parts can be seen moving while it is in operation. Although unsuitable for military use, this relay has already attracted considerable interest in certain quarters.* Technical features include: spark gap reference scale for quick visual juice estimations; fail-safe alarm; Manuel reset; contact unwelding mechanism and pit remover; double-pole, doubtful-throw contacts; ampere turn-signals. Continued observation of the operation of this new Sigma relay will pave the way for even greater discoveries and developments in the field, and permit other things. Basically, that is why none are presently for sale; all are in use by NASAW members who work at Sigma.

In their off moments (coffee break, luncheon bridge game, etc.) sensible members of this group* worked on another relay which is not as spectacular, but is available. A close watch of the Series 42 has shown that this DPDT relay: operates on less than 0.2 watt (DC), less than 0.5 volt-ampere (AC); doesn't chatter, buzz or snore; uses less power (AC version) than — and is interchangeable with — most competitive types; and is rated to switch 5 amperes. The DC version could be used as the output relay in such things as machinery control panels, automatic scales, circuits driven by Sigma Magnetic Amplifiers, and other domestic devices not requiring switching of the saludos amigos variety. It has no spark gap scale, but in normal use this relay will operate many millions of times. More information is contained in a bulletin, available on request.

Sigma Type 42RO Relay; transparent plastic dust cover.

*NORTH AMERICAN SOCIETY OF ARMATURE WATCHERS

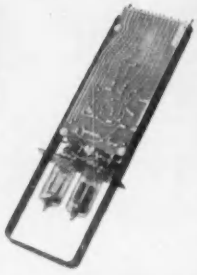
SIGMA

SIGMA INSTRUMENTS, INC.
69 Pearl Street, So. Braintree 85, Mass.

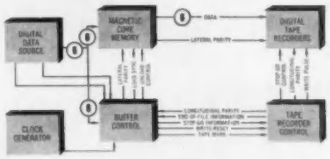
End data format problems

with the NEW EECO

FORMAT CONTROL BUFFER



... Converts input data into compatible format for your individual Data Processing Equipment.



The basic EECO Format Control Buffer accepts digitized data at random rates and produces digital magnetic tapes in the computer Format, suitable for entry into virtually any computer depending on the Format Control Buffer Model. *It can also be furnished to provide for conversion from one computer format to another.* And it can be modified to handle conversion to paper tape, punched cards, or digital plotters.

Input Input can be from such sources as: **Analog-to-digital Converters • Time Registers • Punched Card Readers • Electric Typewriters • Punched Paper Tape • Digital Magnetic Tape**

Source material is presented to the Format Control Buffer as parallel input. Control inputs are normally provided by the data source. And EECO can incorporate a digital multiplexer in the Format Control Buffer to meet your individual requirements for entering data from multiple sources.

Data Input Rate The EECO Format Control Buffer can be set to produce records of any desired length from one to 1024 characters.

Each complete record is read out of the magnetic core memory onto the output magnetic tape at the specified recording density.

Maximum **instantaneous** input rate approximately 40,000 characters per second.

Maximum **average** input rate is limited by average output rate, which, in turn, is determined by the digital recorder tape speed and by the number of characters per record.

Output Format Meets all requirements of the computer format, including parity, check, inter-record and end-of-file gaps, and end-of-file characters or gap.

Construction EECO Computer-Series plug-ins are used extensively. These incorporate specially designed, ultra-conservative circuits to ensure greatest possible reliability.

Full details on the new EECO Format Control Buffer are contained in Bulletin FC-234. Send for your copy today and learn how you can increase the scope of your Data Processing Equipment.

ELECTRONIC ENGINEERS AND PHYSICISTS

EECO offers unusual career opportunities in the creative field of systems and related electronic projects. Send resume of your qualifications to the attention of R. F. Lander.

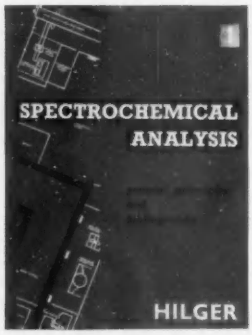
Electronic Engineering Company
of California
1601 East Chestnut Avenue • Santa Ana, California

APPLICATION LITERATURE

(137) HOW TO USE "MAGSLIPS". Muirhead Instruments, Inc. Publication E-1000, 60 pp. This 60-page volume, titled "Muirhead Magslips, Applications and Methods of Use", tells the control systems designer all he needs to know about this company's complete line of self-synchronous devices. Illustrated throughout with photos, graphs, and circuit diagrams, it starts off with a brief history of remote indicating devices and their operating principles, then goes into the development of the Magslip, pointing out certain construction features.

There are separate chapters on systems and circuits, with photos showing some typical industrial applications, on the design and layout of some new applications of pointer indication, synchronous link, and servo operation, on computer applications and on electrical and mechanical details, power supplies, measurements, tests, and trouble shooting.

(138) "SPECTROCHEMICAL ANALYSIS". Hilger & Watts, Ltd. Bulletin CH401, 28 pp. Shown is the cover of a new 28-page illustrated booklet which describes the basic principles of spectrochemical analysis and includes a bibliography



of reference material. Easily understood, it outlines the methods, instruments, and accessories encountered in all phases of spectrochemical analysis, and presents examples of typical analytical problems, laboratory floor plans, and information on special-purpose instruments.

(139) SERVOMULTIPLIERS. Berkeley Div., Beckman Instruments, Inc. "Berkeley Engineering" No. 1, 12 pp. Each issue of this new technical bulletin will contain a feature article plus product news, application literature, and service notes. Present plans are to publish an issue every three months.

Mark Harris, Berkeley engineer, leads off the first issue with an eight-page article on the characteristics of servomultipliers. The first part of the article contains a brief description of their operation and a comparison with an electronic multiplier, the second part, performance, information required to evaluate it, and a discussion of the lack of uniform terminology relating to accuracy and speed of response.

HAGAN RING BALANCE FEATURES — NO. 1

TRIGONOMETRY OF

UNIQUE RANGE CALIBRATION SYSTEM

PROVIDES HIGH SENSITIVITY AT LOW FLOWS

Low-flow sensitivity is a built-in feature of the Hagan Ring Balance flow meter. Rotation of the ring, in response to differential, is governed by the adjustable range spring in accordance with the unvarying trigonometry of the range calibration mechanism. This is expressed by the formula:

$$\text{Spring deflection} = R(1-\cos\theta) - L(1-\cos\phi),$$

and is graphically illustrated at the right. The upper curve shows that the ring motion at low range exceeds the requirement to produce pen motion linear with flow. Thus, the cam which transmits ring motion to the pen arm can convert this excess ring motion into extra power for precise pen movement.

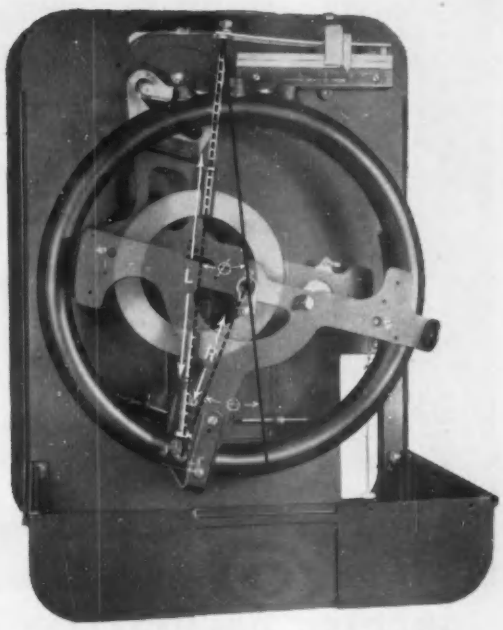
METERING APPLICATIONS WHICH REQUIRE WIDE TURN-DOWN CALL FOR HAGAN RING BALANCE METERS. You get this feature when you specify Hagan, as well as the following:

1. Ease of calibration under operating static pressures with factory calibrated check weights! No more four-story water columns and telephones!
2. Safe operation with rings rated at 2,500, 10,000, 15,000 psig. No gaskets, no stuffing boxes.
3. Sealing fluid density and level not critical. No eyedroppers required.
4. Interchangeable ring assemblies for full scale ranges from 0.5" w.c. to 560" w.c. Adjustment on any one ring over a 7:1 differential range.
5. Wide range computation and/or compensation by means of built-in, easily checked mechanisms available on most models.
6. Pneumatic or electric transmission also available.

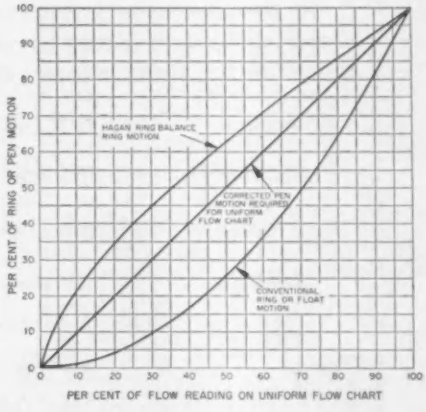
Bulletin MSP-141 describes these features and the new design of the Hagan Ring Balance meter case. ASK US FOR IT.

HAGAN CHEMICALS & CONTROLS, INC.

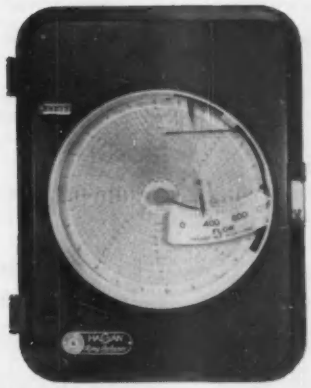
HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY · HALL LABORATORIES



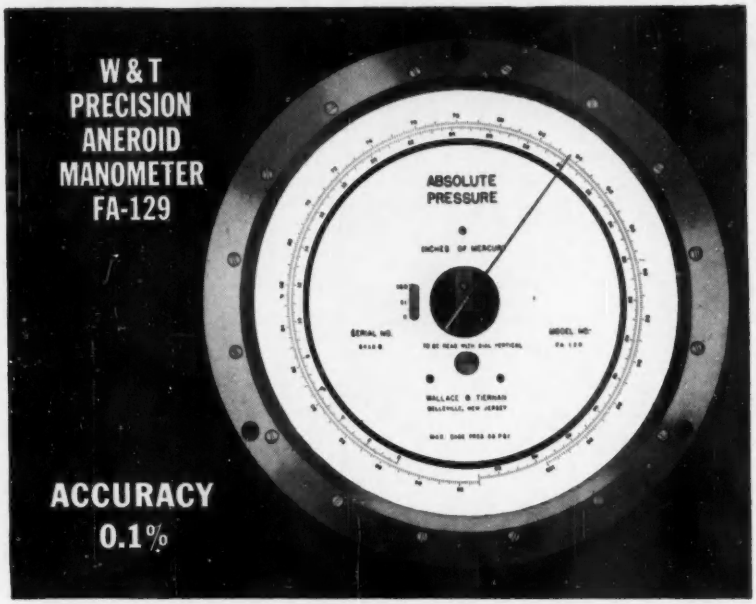
Push rod moves upward against range spring, governing ring rotation in accordance with the diagram below.


PER CENT OF RING OR PEN MOTION
PER CENT OF FLOW READING ON UNIFORM FLOW CHART
HAGAN RING BALANCE RING MOTION
CORRECTED PEN MOTION REQUIRED FOR UNIFORM FLOW CHART
CONVENTIONAL RING OR FLOAT MOTION

Excess motion of the Hagan ring, as shown by upper curve, is converted (with a gain in torque) into linear pen movement by a gently sloping cam.



New, rigid, weatherproof, die-cast, aluminum case. Four-piece back for complete accessibility.



PRECISE CALIBRATING STANDARD
...For Absolute Pressure Work

Ranges: 0 to 31.5 inches of Hg. absolute (min.)
0 to 100 inches of Hg. absolute (max.)
Other intermediate ranges available

Accuracy: 1/1000 of full scale

Sensitivity: 1/10,000 in *all* ranges

Scale Length: 45 inches in two revolutions

Dial Size: 8½ inch diameter

Write for Publication No. TP-15-A

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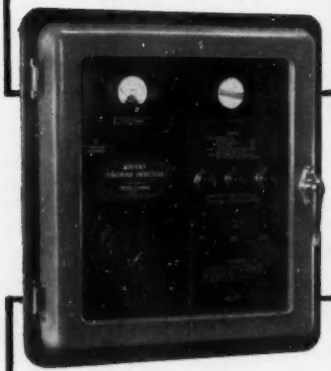
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY
In Canada, Wallace & Tiernan, Ltd. — Toronto A-112



HOW TO DETECT
3 PARTS CHLORINE
IN A MILLION PARTS AIR

New W&T Solvay Chlorine Detector*
detects as little as 3 p.p.m. chlorine in a continuous air-stream sample. Automatically sets off alarm at higher concentrations.
Write for Publication 50.118

WALLACE & TIERNAN
INCORPORATED
25 MAIN ST., BELLEVILLE 9, N. J.

1-55 *Manufactured under patent license from Solvay Process Div., Allied Chemical & Dye Corp.

NEW PRODUCTS

precise 5-deg steps, all with no additional fixturing. A novel ball-detent mechanism does the rotating and a fine-angle device spans the interval between steps. Synchro sizes 8 to 31 can be accommodated. The unit measures 12 in. in diam by 5¾ in. high.—Theta Instrument Corp., East Paterson, N. J.

Circle No. 33 on reply card

COMPONENT PARTS

FLEXIBLE PREAMP

A new photomultiplier preamplifier, the N-352, designed for greater flexibility in scintillation spectroscopy, features a pre-wired photomultiplier socket and stacked cathode follower with a 70-ohm output impedance mounted in a counter-weighted aluminum box. It is particularly suitable for driving long coaxial cables with characteristic impedances between 65 and 78 ohms.—Hamner Electronics Co., Princeton, N. J.

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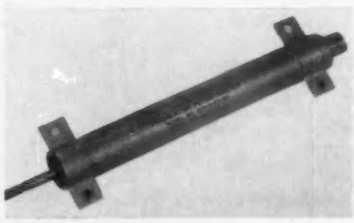
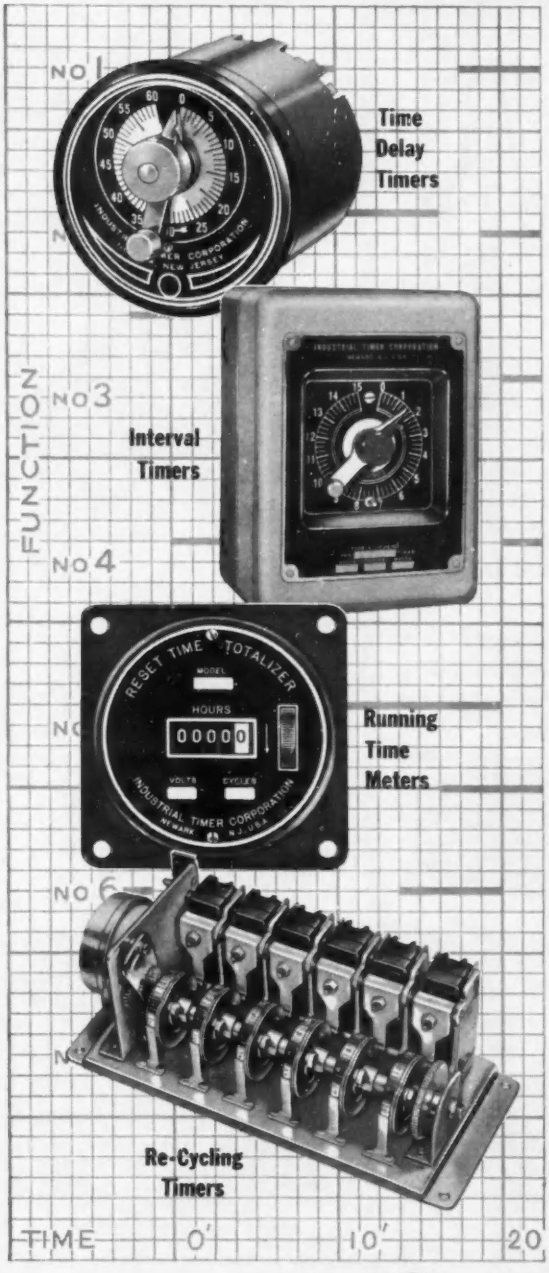


RECTILINEAR POT

The Model G rectilinear potentiometer will operate accurately under vibration conditions up to 20 g's and

Need a "SPECIAL" TIMER ...need a "STANDARD"?



Here's why WE can give you the fastest service

When you want a timer, you want one that fits your needs 100% — and you want it *fast*. Get in touch with Industrial and you'll get both. Because:

In our 20 years of experience, we have developed *over a thousand combinations* from our 17 basic types, to meet the widely varying needs of our customers. Therefore — many jobs that would seem to require a "special" timer are in fact a "standard" timer with us. Here is one tremendous saving of time for you.

When you do need a special timer, this same wealth of experience goes to work for you at once to design it. Our Engineering Department not only originates new designs, but also develops modifications for that purpose. That's why requests for special timers can be filled without delay.

Each method — designing for a standard timer or for a special timer — has its advantages. Designing for an already available timer means lower costs, faster service, simplified replacements.

Designing for a special timer has its advantages too. It means you'll fulfill your needs 100% — no need to limit your designing horizons. Either way — standard or special — you'll get the timer you want most promptly from Industrial.

Or perhaps you need quick service on timers for automatic controls. Here too Industrial Timer is your first source of supply. For in this field Industrial has a big head start. True, each automatic control job is a bit different from the rest. But the record shows that our years of timer experience has given us the special knowledge it takes to give you the right answers in near-record time.

So, for the utmost in all-round timer service, it's Industrial that offers you this outstanding combination: deliveries "Immediate on Standards . . . First on Specials." Plus the experience of one of the foremost group of timer engineers in the nation.

Timers that Control the Pulse Beat of Industry

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TELEPHONE INSTRUMENTS — Desk phones, in black and 7 color-tones. Wall phones. Units engineered to specifications.

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North is a manufacturer and prime supplier of these and many other communication components for original equipment manufacturers. All North equipment is backed by over 75 years' experience in the communications and electronics fields.

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INDUSTRIAL DIVISION

NORTH ELECTRIC COMPANY

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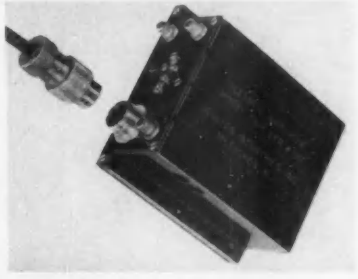
NEW PRODUCTS

in temperature environments to 400 deg F. Designed primarily for airborne service, the unit features all stainless-steel externals. Double seals at the actuation shaft protect the interior against humidity and foreign particles. Mounting configurations include flanges, integral ball joint, threaded case, etc. Unit is available in ranges from 0.5 to 10 in. with resistances from 500 to 10,000 ohms per in.–Servonic Instruments, Inc., Pasadena, Calif.

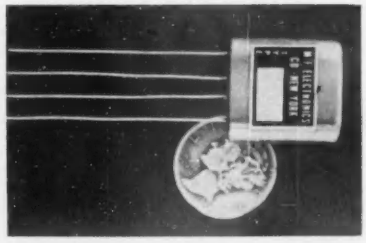
Circle No. 35 on reply card



AIRBORNE AMPLIFIER

This low microphonic voltage amplifier for aircraft, and other structures where size, weight, power consumption, and vibration are prime considerations, provides both fixed and variable gains (from 10.2 to 99.5 variable and 10 to 100 fixed). Gain remains constant over a wide range of plate voltages. Where extreme environmental conditions warrant it, the entire unit can be potted.–Gulton Industries, Inc., Metuchen, N. J.

Circle No. 36 on reply card



TRANSISTOR ASSEMBLIES

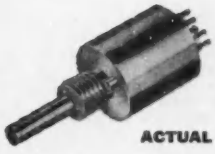
Shown is one of a complete line of transistor assemblies including flip-flops, multivibrators, and amplifiers, that lend themselves nicely to the latest modular construction techniques. Example: one bit may now be stored in the Type 11 flip-flop in

DeJUR precision potentiometers

...THE ONE BEST ANSWER TO YOUR DESIGN PROBLEMS

SERIES C-050

SUB-MINIATURE ½" • SEALED CONSTRUCTION



ACTUAL SIZE

- One piece nickel plated bronze case and bearing.
- Electrical rotation–320°; Mechanical rotation–325°, or continuous 360°
- Voltage breakdown–1000 volts AC.
- Threaded bushing mounting.

SERIES C-078

MINIATURE ⅞" • GANGED MULTIPLES • INDEPENDENT PHASING

ACTUAL SIZE

- Unit height ⅜"; weight ½ oz.
- Independent linearity: ± 1% is standard.
- Linear or non-linear windings on flat card; res. tol. – ± 5% std., ± 1% on order.

SERIES C-158

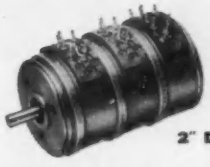
INTERMEDIATE 1¾" • GANGED MULTIPLES • INDEPENDENT PHASING

¼ ACTUAL SIZE

- Independent linearity: ± 0.5% of total resistance is standard.
- Linear or non-linear windings std., ± 1% on order. on flat card; res. tol – ± 5%
- Rotation: electrical – 320°. Mechanical–325°.

SERIES C-200 (sleeve bearing) BC-200 (ball bearing)

IN-FIELD GANGING • UNLIMITED MULTIPLES • ADJUSTABLE TAPS



2" DIAM.

- Resistance ± 5% standard; to ± 1% on special order.
- Linearity: ± 0.5% independent linearity is standard; ± 0.3% on special order for C-200; ± 0.2% on special order for BC-200.
- Mounting: Servo type or single hole mounting with optional non-turn device.

SERIES C-300

SINE-COSINE

3" DIAM.

- Independent brush contacts produce accurate sine and cosine outputs.
- Function accuracies of ± 1% are standard.
- Multiple ganged units are available.

SERIES KS-200 (sleeve bearing) K-200 (ball bearing)

LONG FUNCTION ANGLES • CLAMP PHASING • HIGH RESOLUTION

2" DIAM.

- Resistance: linear, on triple Formvar copper mandrel.
- Independent linearity: ± 0.5% is standard; ± .1% on order.
- K-200 pots are completely enclosed and may be used as single or multiple ganged units.

SERIES HP-200, HP-300, HP-500

HIGH RESOLUTION • LONG FUNCTION ANGLES • GANGING MULTIPLES

2", 3", 5" DIAM.

- Linearity: ± .5% standard to ± .1% on order.
- Resistance: ± 5% standard to ± 1% on order.
- Rotation: 360° mechanical; 356° ± ½° electrical standard.

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Our engineering department can supply prototypes to meet unusual design specifications for tests and approval. Send us your specs for analysis. Electronic Sales Division, DeJUR-Amsco Corporation, 45-01 Northern Blvd., Long Island City 1, New York.

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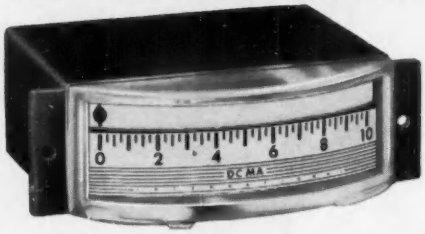
SIDE INDICATOR PANEL METERS



MODEL 1145

APPROX. ½ ACTUAL SIZE

- THREE SIZES—Models 1145, 1135, 1120
- Horizontal or Vertical Mounting
- Maximum Accuracy and Readability

Save space on crowded, complex electronic controls and other panels without sacrificing accuracy or readability. These instruments provide same scale length as comparable conventional round meters, but occupy only 1/3 the panel area and are ideal for the redesigning and streamlining of panels. The wide range of standard and special ranges includes Expanded Scale Voltmeters, VU and DB meters.

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international ii *instruments*

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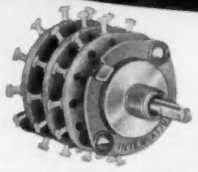


sub-miniature

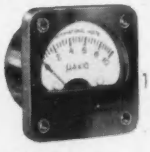
ROTARY SWITCH

- Up to 12 Positions per Deck
- Up to 3 Decks

A low-contact-resistance switch ideal for use in all electronic and test equipment applications where small size plus peak performance are essential. Available with 1, 2, 3 or 4 poles on each deck and with either shorting or non-shorting contacts; or rotor contacts shorting out any variations from 2 to 11 positions. Features include: specially impregnated glass melamine wafer, solder type lugs, and positive indexing.

1" ROUND and 1½" ROUND and SQUARE METERS

1" Meters have full 90° scale arc, scale length .760" 1½" meters to Military Specifications MIL-M-3823 and MIL-M-10304 (Sig. C.) Also self-contained VU and DB meters, and illuminated models with lamp housing attached.



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1½" Ruggedized Meters • 1" and 1½" Panel Meters • 1½" VU, DB and Illuminated Meters • Miniature Multitesters • Side Indicators

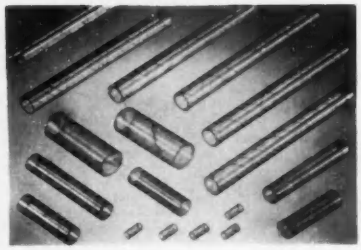
P.O. BOX 2954, NEW HAVEN 15, CONNECTICUT

NEW PRODUCTS

¼ in., allowing approximately 7,500 bits per cu ft at fast access speeds. Equivalent component density is 60,000 to 125,000 parts per cu ft. In addition to their subminiature size, these units feature: operation in temperatures from minus 25 deg C to plus 50 deg C, operation under water, and low operating voltages.—M F Electronics Co., New York, N. Y.

Circle No. 37 on reply card

ACCESSORIES & MATERIALS



MYLAR TUBES

A new line of du Pont Mylar thin-wall coil forms has been developed for insulating where space is at a premium. Supplied in thicknesses from 0.002 to 0.010 in., the material is highly resistant to moisture, solvents, and chemicals. It has a higher dielectric strength than many other flexible insulating materials, a high tensile strength, and excellent thermal characteristics. Tubes are fabricated to customer specifications.—Precision Paper Tube Co., Chicago, Ill.

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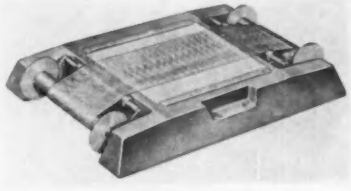

RECORD REVIEWER

The Oscillograph Viewpak, a simple, portable device for rapid reviewing or editing of oscillographic or other strip chart records, features a motorized paper drive and a 16- by 18-in. backlighted viewing area, and will handle

Bill Erickson discusses MAGNETIC TAPE RECORDING

Most phenomena that can be depicted electrically can be recorded on magnetic tape. Long-known but relatively recently perfected, magnetic tape recording has won wide acceptance as a particularly valuable tool in data-handling and process control applications. The very nature and versatility of this tool, however, require the most mature judgment in its use, lest unwarranted enthusiasm lead to misapplications and incorrect results.

In the field of industrial control, magnetic tape recording has been used most effectively for the storage of electrical analog information in such processes as conveyor control for article sorting, machine tool and pattern control, dry and liquid food batch mixing, and so forth. In data-handling problems, it has served the engineer in speeding analyses of complex physical phenomena. In communications experiments, multi-channel tape units have provided the scientist with simulation of otherwise physically unrealizeable filters. In all these instances, the merit of magnetic tape recording lies in its ability to store electrical analog information and make it available for play-back, or re-run, as often as may be necessary.

Of the few methods available to "advance" or "retard" time, none is as practical as the use of magnetic tape. For instance, it is frequently overlooked that a tape recording can be considered as a variable delay line of considerable equivalent electrical length. Merely by varying the play-back speed, or the relative position of the reproduce heads, or both, one line (or tape) can be used to delay a number of signals relative to each other, one signal relative to a number of others, or to some external source.

Despite this versatility there are definite limits of usefulness within which the application of tape recording should be confined. Such a limit is typified in the problem of signal "dropout." By this is meant the distortion, or even complete loss, of a signal caused by the presence of minute nodules in the tape itself. The occurrence of such imperfections is completely random and can be controlled only during production of the tape. And while significant progress has been made in recent years to improve the quality of tape, ultimate perfection has not yet been achieved.

In data-handling and process control fields, the use of magnetic tape recording is particularly well-suited to digital techniques where large quantities of information can be stored most economically in a minimum amount of space. In all applications where high-speed random access is not required, magnetic tape recording provides a relatively inexpensive and wholly suitable solution to the recurring information storage problem. Here signal dropout is virtually eliminated because the electrical impulses are of a pulse present-pulse omission presentation and are recorded at, or very near, the tape saturation level.

Wilbur Erickson, systems engineer, specializing in input-output equipment, discusses magnetic tape recording.

The use of magnetic tape recording is, at one and the same time, the prerogative and the responsibility of the systems engineer. His experience and ability to make intelligent use of this one of the many tools available to him, will define his stature as a systems man. The potential of magnetic tape recording in systems has barely been scratched, but the applications to which it can, and undoubtedly will, be put are as limitless as man's imagination to devise them.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

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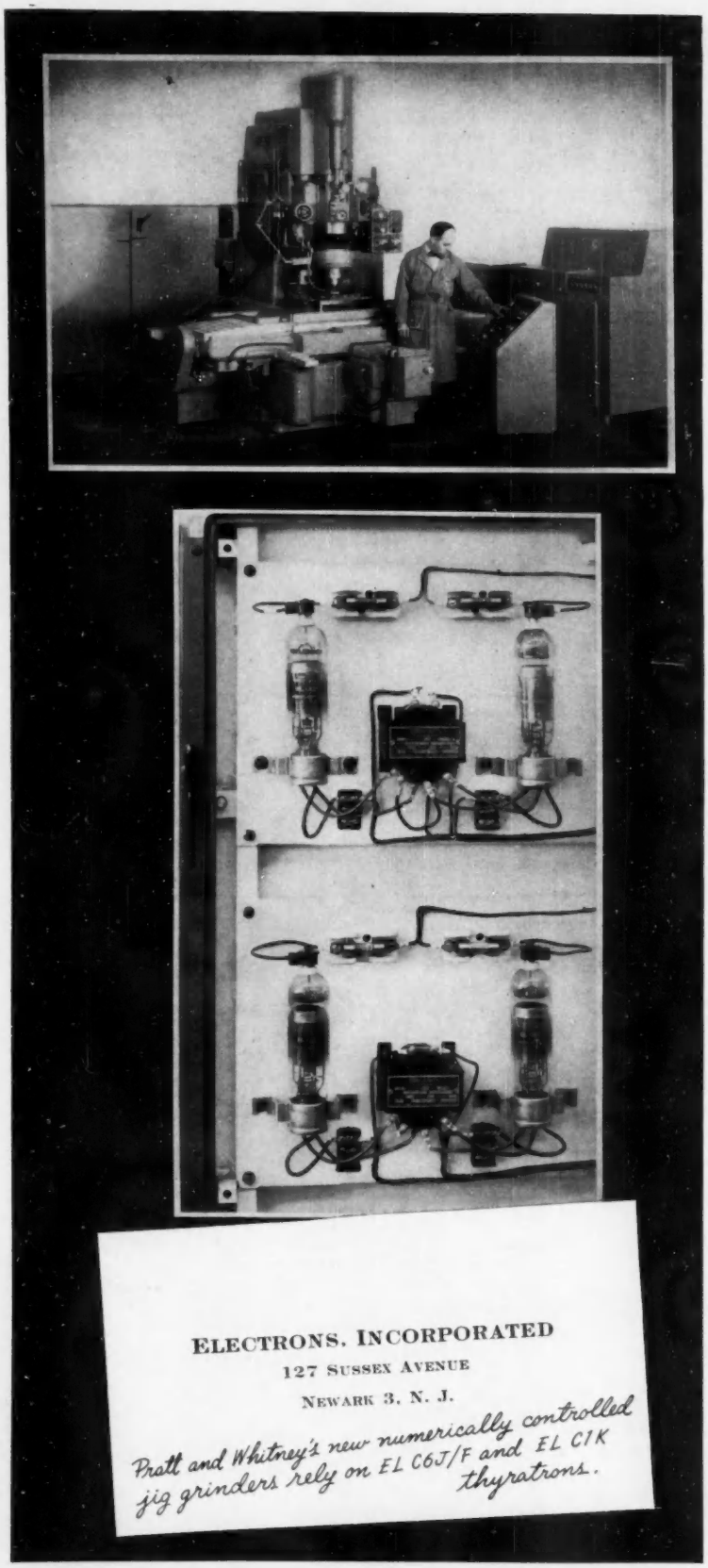
ELECTRONS. INCORPORATED
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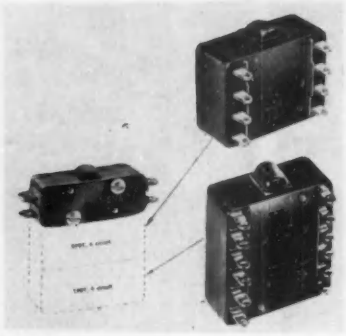
Pratt and Whitney's new numerically controlled jig grinders rely on EL C6J/F and EL C1K thyratrons.

NEW PRODUCTS

records up to 16 in. wide in rolls up to 7½ in. in diam. A foot pedal varies linear speed of the record from 0 to approximately 96 in. per sec. Unit has an aluminum frame enclosed in a fibre-glass case.—Benson-Lehner Corp., Los Angeles, Calif.

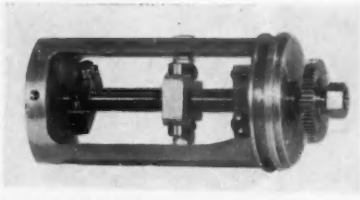
Circle No. 39 on reply card



PUSHBUTTON

The manual A4-67 actuator can accept any one of the company's three basic switches without altering the bracket, thus permitting a number of circuit arrangements from SPST to TPDT-6 circuit. A knurled ring nut speeds hand installation on panels from ⅛ to ½ in. thick. The large actuator buttons are available in standard colors of black, red, and green.—Electro Snap Switch & Mfg. Co., Chicago, Ill.

Circle No. 40 on reply card



LIMIT STOP

Contained in a size-11 synchro housing, this miniature mechanical limit stop needs no special mounting hardware for direct use in production servo systems. A lead screw type, it permits a total travel of 40 revolutions and can be continuously set over its full range without being removed from the mechanical system. According to the manufacturer, the unit meets all applicable military specs.—Reeves Instrument Corp., New York.

Circle No. 41 on reply card

Three Genisco Accelerometers help the Super Sabre close in

If enemy air infiltration happens, you can be sure that modern knights of the sky powering the swift *Super Sabre* at speeds faster than sound will spearhead America's defense.

Typical of today's supersonic aeronautics, the USAF's *Super Sabre* reflects the finest contemporary engineering skill and scientific creative imagination. But this swept-wing assassin is more than just another jet-powered plane. It is a proven, integrated electro-mechanical system, combining a multitude of precision sub-systems, assemblies, and individual parts.

The automatic flight control system, for example, consists of numerous components, each one vital to the performance of the system. Naturally, component reliability is imperative if the plane is to carry out its mission. The flight control system of the F100D incorporates three Genisco Model DDL Accelerometers.

The Model DDL is only one of many Genisco Accelerometers now in use on America's air guardians, including our most important operational guided missiles. Like other models, the DDL was designed for a particular application—to function perfectly in the severe vibrational and shock environment of supersonic flight.

Genisco's ability to design for the most stringent applications and to produce precision instruments in large quantities has made the company an important link in our nation's defense chain.

Descriptive technical data on the Model DDL and other Genisco accelerometers will be sent upon request.

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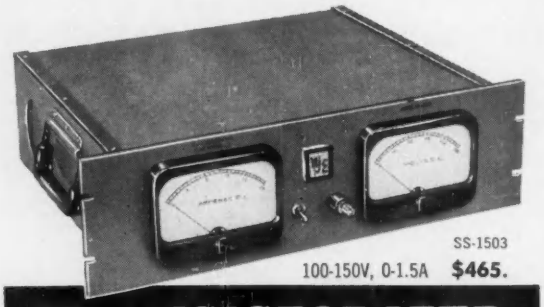

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100-150V, 0-1.5A **$465.**

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Not just tubeless . . . really dependable. NJE's new Solid State power supplies are short-circuit proof, tubeless, use only hermetically-sealed transformers and chokes, wire-wound resistors. All components derated 25%. Cooler, lighter, much smaller. Zerolagged, 0.1% regulation, one millivolt of ripple.

. . . And here's the crusher—they cost far less than inferior vacuum-tube equipment! **WRITE FOR CATALOG.**

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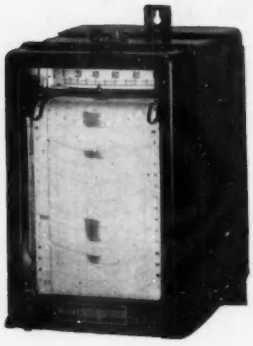
Constant attention to the wants and needs of users, has been worked into the finished recorder by trained designers, who devote their entire effort to producing the best in direct-writing recorders. *E-A Recorders are designed to be the best.* Performance has proved their superiority.



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Pioneers in the Manufacture of Graphic Instruments
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WHAT'S NEW

(Continued from page 46)

dent of the AIEE. The former AIEE treasurer was elected at the annual meeting of the association in Montreal, Can., last June, heading a ten-man slate that included a new treasurer, five vice-presidents and three directors.

Barrett's successor is L. F. Hickernell, chief engineer of Anaconda Wire & Cable Co. Both men are AIEE fellows. The new vice-presidents are: Benjamin R. Teare Jr., dean of engineering and science, Carnegie Tech; Herbert W. Oetinger, Duke Power Co., Charlotte, N. C.; Albert C. Johnson, Omaha Public Power District; Orien A. Gustafson, Pacific Northwest District, General Electric Co.; and Gordon F. Trace, head of the Electrical Engineering Dept., University of Toronto.

Directors elected were: Edwin W. Morris, Westinghouse Electric Corp.; William R. Clark, Leeds & Northrup Co.; and Julius C. Strasbourger, Cleveland Electric Illuminating Co.

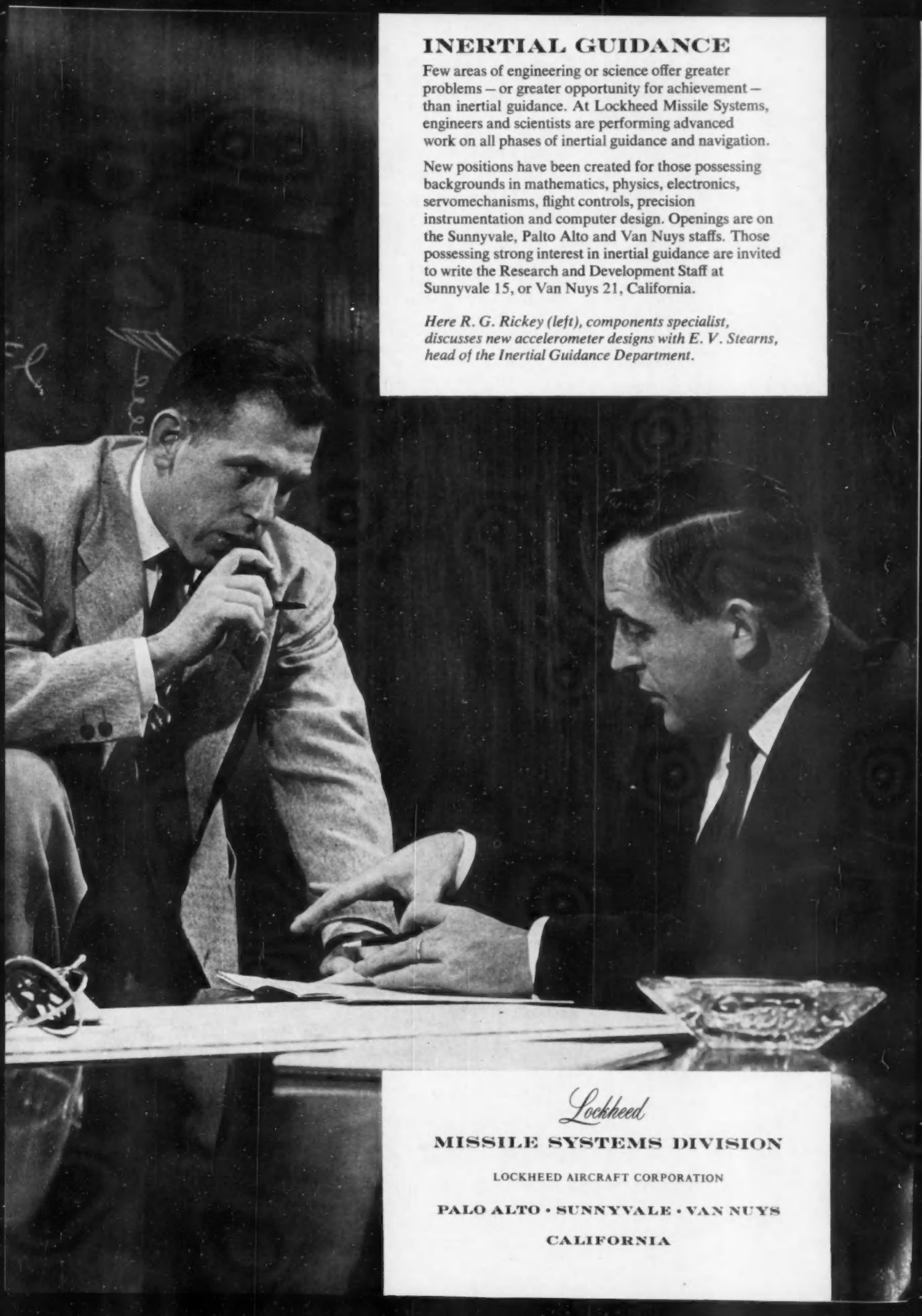
Barrett has been treasurer since 1953 and AIEE representative on the board of the United Engineering Trustees since 1951. He became president of UET in 1955, and it was largely through his efforts that this group was given responsibility for providing a new national headquarters building for engineering in New York City.

James N. Landis, who will take over as president of the ASME in December, the time of the annual meeting, is vice-president of Bechtel Corp. He was nominated at the semi-annual banquet in New York last June, together with these candidates for positions of regional vice-presidents and directors:

Charles E. Crede, Barry Controls, Inc., Region I; Arthur W. Weber, Corning Glass Works, Region II; Ernest W. Allardt, The Babcock & Wilcox Co., Region V; Henry S. Aurand, U. S. Army (retired), Region VII; L. N. Rowley Jr., editor of "Power", director of administrative activities; Elmer O. Bergman, C. F. Braun & Co., director of codes and standards; and Ronald B. Smith, The M. W. Kellogg Co., director of technological activities.

Landis, who will succeed William F. Ryan, vice-president of Stone & Webster Engineering Corp., has been with Bechtel since 1948, first as chief power engineer, then as vice-president in charge of commercial power work for the generation of electricity. He and Allardt are ASME fellows.

At the same time comes news that



INERTIAL GUIDANCE

Few areas of engineering or science offer greater problems – or greater opportunity for achievement – than inertial guidance. At Lockheed Missile Systems, engineers and scientists are performing advanced work on all phases of inertial guidance and navigation.

New positions have been created for those possessing backgrounds in mathematics, physics, electronics, servomechanisms, flight controls, precision instrumentation and computer design. Openings are on the Sunnyvale, Palto Alto and Van Nuys staffs. Those possessing strong interest in inertial guidance are invited to write the Research and Development Staff at Sunnyvale 15, or Van Nuys 21, California.

Here R. G. Rickey (left), components specialist, discusses new accelerometer designs with E. V. Stearns, head of the Inertial Guidance Department.

Lockheed

MISSILE SYSTEMS DIVISION

LOCKHEED AIRCRAFT CORPORATION

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NOW YOU CAN BUY OFF THE SHELF!

for extreme accuracy in transmitting signals . . .

SHIPMENT GUARANTEED WITHIN 10 DAYS FOR COMMERCIAL UNITS

. . . and within 30 days for Mil Spec units.

THESE UNITS ARE NOW ON THE SHELF

(subject to prior sale)

1HG	1HDG	3HCT	5F	1HG400*
1F	3HG	3HDG	5D	1F400*
1HCT	3F	5HG	5HDG	IHCT400*

* 400cy units are available to commercial specs only. All others are available to both military and commercial specs.

In addition to above units, Ford Instrument currently has many sizes and types of synchros in production and approaching shelf status — also specials. Call or wire R. Banka, Component Sales Division (STillwell 4-9000 Ext. 513) for prices, or check and mail coupon below, stating quantity. Check coupon space indicated if you wish FREE booklet on Ford's complete synchro line.

Component Sales Division
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Please send me prices and characteristics of the units checked below:

☐ 1HG	☐ 3F	☐ 5D
☐ 1F	☐ 3HCT	☐ 5HDG
☐ 1HCT	☐ 3HDG	☐ 1HG400*
☐ 1HDG	☐ 5HG	☐ 1F400*
☐ 3HG	☐ 5F	☐ 1HCT400*

*Available to commercial specs only.

☐ Units should meet military specs.

☐ Please send me FREE booklet.

Name_____

Position_____

Company_____

Street_____

City_____ State_____

WHAT'S NEW

Oscar B. Schier II has succeeded Clarence E. Davies as ASME secretary-elect. Davies has held this chief administrative post for 23 years.

Other Important Moves

► **Nathaniel B. Nichols,** who was Taylor Instrument Co.'s director of research before leaving industry to go into teaching, has returned to the company as chief engineer. He succeeds **Ralph E. Clarridge,** who joins the president's staff as a new product specialist. Nichols' teaching stint was at the University of Minnesota, where he was professor of electrical engineering. He left there after a while to return to industry as assistant vice-president and manager of commercial engineering for Raytheon Mfg. Co. During the war he worked in MIT's Servomechanisms and Radiation laboratories. He is a consistent article writer and speaker.

► Changes in two Beckman Instruments divisions involve **Anthony Del Duca,** named chief electronics engineer for the Process Instruments Div., and **Ernest M. Whitley,** named production engineer for the Spinco Div. Del Duca, formerly a senior engineer, will direct design work for electronic circuitry. He has had previous experience with North American Aviation and Convair. Whitley, who will guide industrial design programs centering around Spinco medical instruments, comes from Beckman & Whitley, Inc., where he was vice-president and chief engineer.

► American Machine & Foundry's new director of engineering in the Rochester (N. Y.) Div. is **Wilfred E. Walton,** formerly with General Electric Co. His arrival at AMF coincides with the promotion of **Robert K. Winkleblack,** a nuclear engineer, to assistant manager of the Nuclear Engineering Laboratory. Winkleblack came to AMF in 1956 from Combustion Engineering, Inc. He has also been with Argonne National Laboratory, in charge of the design and development of water-cooled nuclear power reactors, and Wright Aeronautical Corp.

► **Morris Rubinoff** has left the University of Pennsylvania, where he was an associate professor in electrical engineering, to become manager of digital computer engineering in Philco Corp.'s Government & Industrial Div. Rubinoff, who will concentrate on R&D work for Philco's new Transac data processor, has been associated with other educational institutions, too: University of Toronto (wartime research on the proximity fuse), Harvard (applied science fellowship, instructor in physics), and the Institute for Advanced Study.

► Potter & Brumfield, Inc., has named **E. W. Gentz,** formerly vice-president and general manager of the Automotive Div. of Sparks Withington Co.,

W. J. Barrett

N. B. Nichols

Anthony Del Duca

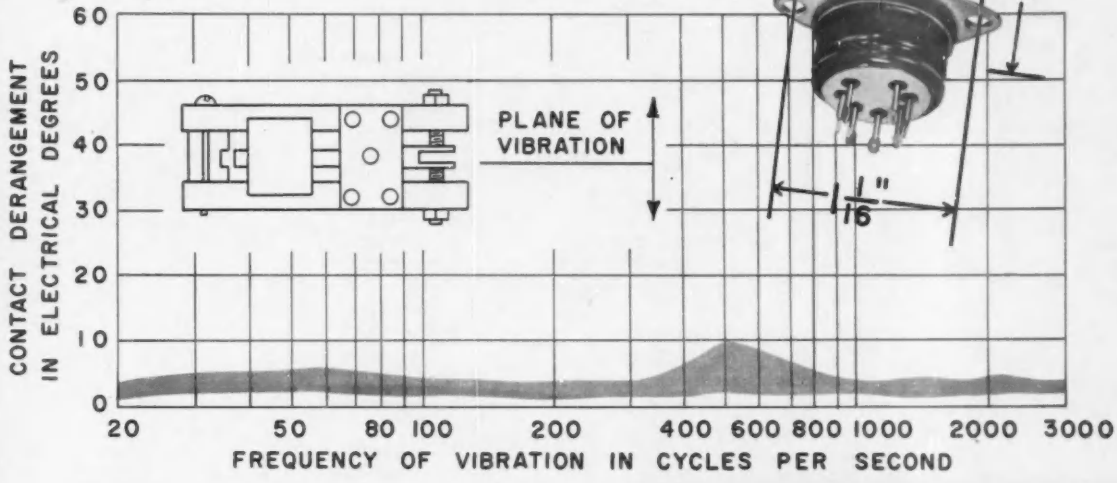
W. E. Walton

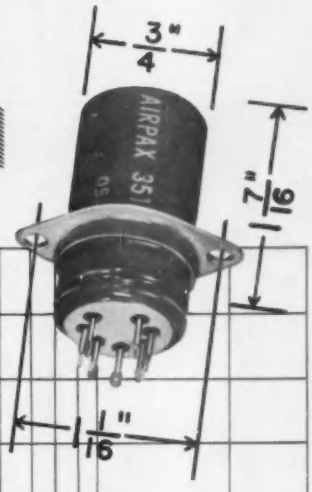
Morris Rubinoff

E. W. Gentz

BALANCED ARMATURE CHOPPER

withstands SHOCK and VIBRATION





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Voltage ..... 6.3 ± 0.6 RMS volts

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Balance ..... within 15 electrical deg.
Phase Angle ... 65 elect. deg. nominal
Voltage ..... up to 100 DC volts
Current ..... up to 2 milliamperes
Noise ..... 200 microvolts average

Environment

Vibration .... 10 to 2500 CPS at 15 G
Shock ..... 50 G in any direction
Temperature ..... —65 C to +125 C

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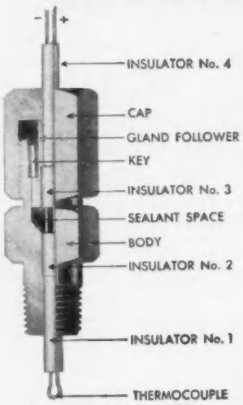

U. S. PATENT 2,625,573

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WHAT'S NEW

director of manufacturing. He succeeds **Howard Meuche,** who has left to become president and general manager of Universal Scientific Co., Inc. Gentz has also been with Engineering & Research Corp. and Bohn Refrigeration Co.

▶Two changes at Vickers, Inc., involve **Robert A. Erskine,** who becomes chief engineer in the Machinery Hydraulics Div. of the Industrial Dept., and **Carl E. Gunther,** who takes over a similar slot in the Marine & Ordnance Dept. Erskine, most recently staff assistant

R. A. Erskine

C. E. Gunther

to the vice-president and director of engineering, joined Vickers in 1935. He will be located at Detroit. Gunther, who will work out of Waterbury, Conn., had been chief engineer of the Waterbury Tool Div. He came to Vickers in 1956 from Aircraft Products Co.

▶The new chief in the Precision Potentiometer Div. of General Controls Co. is **Max Moore,** who came to the company last year from Spectrol Corp., where he was a project engineer.

▶**Cledo Brunetti,** managing director of General Mills's Mechanical Div., the research unit that is doing work in guided missiles and automation, has left to go with Food Machinery & Chemical Corp. as assistant to the executive vice-president. FM&C is also doing a hot business in missiles, as well as in automatic machinery and chemicals.

▶As manager of the Data Processing Section of Electronic Control Systems, Inc., **Kenneth M. Rehler** will be responsible for analysis, design, and development of special-purpose analog and digital computers for commerce and the military. He was formerly vice-president of Computer Control Co., Inc.

▶**John P. Klembeth,** formerly production manager for Robertshaw-Fulton's Fielden Instrument Div., is the new assistant chief engineer of Milton Roy Co. Klembeth, who has close familiarity with electromechanical design of instrumentation systems and with manufacturing management, has

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WHAT'S NEW

also been with Minneapolis-Honeywell's Brown Instrument Div. The new R&D manager in the Analytical Instrument Div. is **George W. Schneider.**

▶ **Edward Foodim**, formerly chief engineer of Consolidated Avionics Corp. and a specialist in large-scale data-reduction instrumentation systems, has been promoted to assistant to the president. The new chief, **Ira L. Kasindorf,** comes to Con Avionics from

Edward Foodim

I. L. Kasindorf

Servomechanisms, Inc., where he was chief engineer of the Components Div. Before that he was with Airborne Instruments Laboratories, Inc., and the NACA.

▶ Lewis & Kaufman, Ltd., a division of International Glass Corp., has a new chief engineer for R&D and design of electron tubes. He is **Walter R. Clinton,** a physicist and mathematician who has been associated with the University of California's Radiation Laboratory, Penta Laboratories, and the GE Microwave Laboratory.

▶ **William W. Martenis,** manager of Minneapolis-Honeywell's new product extension activities, will continue in this capacity as head of all semiconductor work. His new duties will involve power transistors.

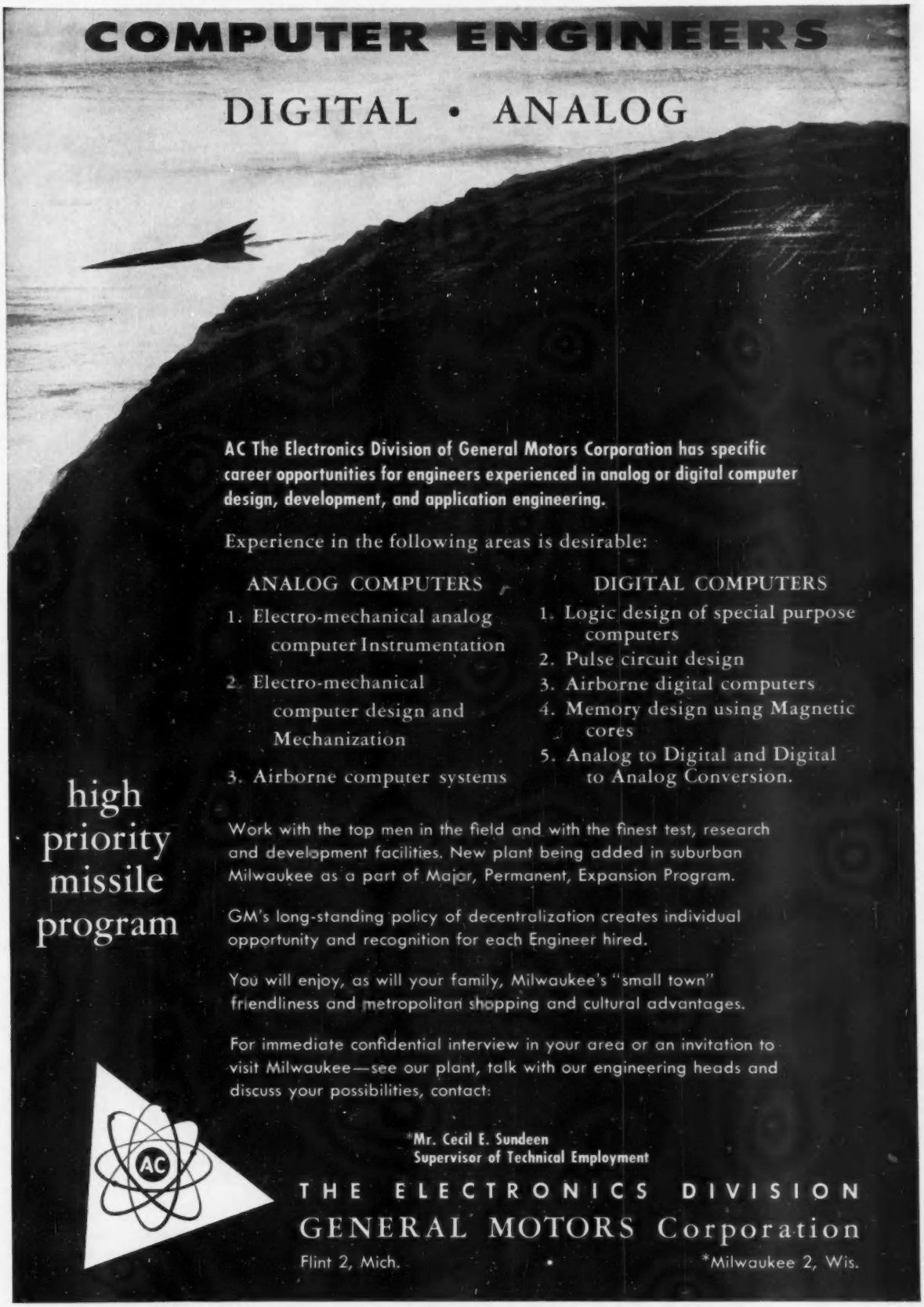
▶ In a top-level election at Varian Associates, **H. Myrl Stearns** was named president, **Sigurd F. Varian,** chief engineer, was named vice-chairman of the board, and **Emmet G. Cameron** and **Howard R. Patterson** were named vice-presidents. The changes free Sigurd Varian for more technological work, provide Chairman Russell Varian with two assistant policy-makers, and put Cameron in charge of all operating divisions and Patterson in charge of the Tube Div.

▶ **DeWitt H. Pickens,** formerly project manager for Tammen & Denison, Inc., has been named manager of electronic R&D at Chicago.

▶ Two division managers have been elected vice-presidents by Westinghouse Electric Corp. They are: **John H. Chiles Jr.,** manager of the Transformer Div. at Sharon, Pa., and **B. M.**

COMPUTER ENGINEERS

DIGITAL • ANALOG



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1. Logic design of special purpose computers
2. Pulse circuit design
3. Airborne digital computers
4. Memory design using Magnetic cores
5. Analog to Digital and Digital to Analog Conversion.

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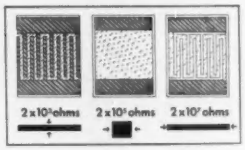

- Signal-to-noise ratio is excellent, particularly in the infrared.
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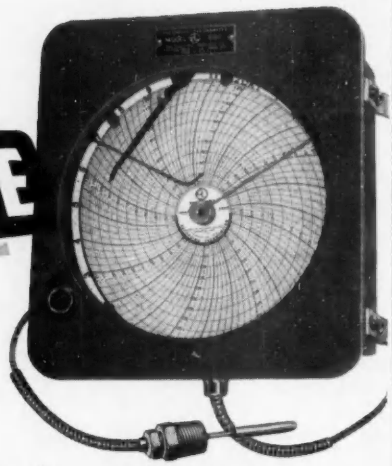

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WHAT'S NEW

Brown, manager of the Baltimore divisions. Chiles has been with the company since 1926. Brown, there since 1931, directs the work of four plants in communications, fire-control, and torpedo and missile electronic devices.

▶Allen B. Du Mont Laboratories, Inc., has elected a new vice-president for tube operations. He is **Stanley J. Koch,** formerly general manager of the Television and Industrial Tube divisions. A member of the Du Mont group that developed the first practical cathode-ray tubes, Koch became head of CRT activities in 1937, later established the Tube Development Laboratory, and in 1956 was named director of the Tube Research Div.

▶**Bill Waddell,** the new chief engineer for new products at the Systems Div. of Daystrom, Inc., was formerly technical assistant to the general manager of G. M. Giannini & Co. Before that, he was with Northrop Aircraft as head of a computation-to-analysis project, with Electronic Associates as senior engineer, and with Librascope as an electronic-equipment designer.

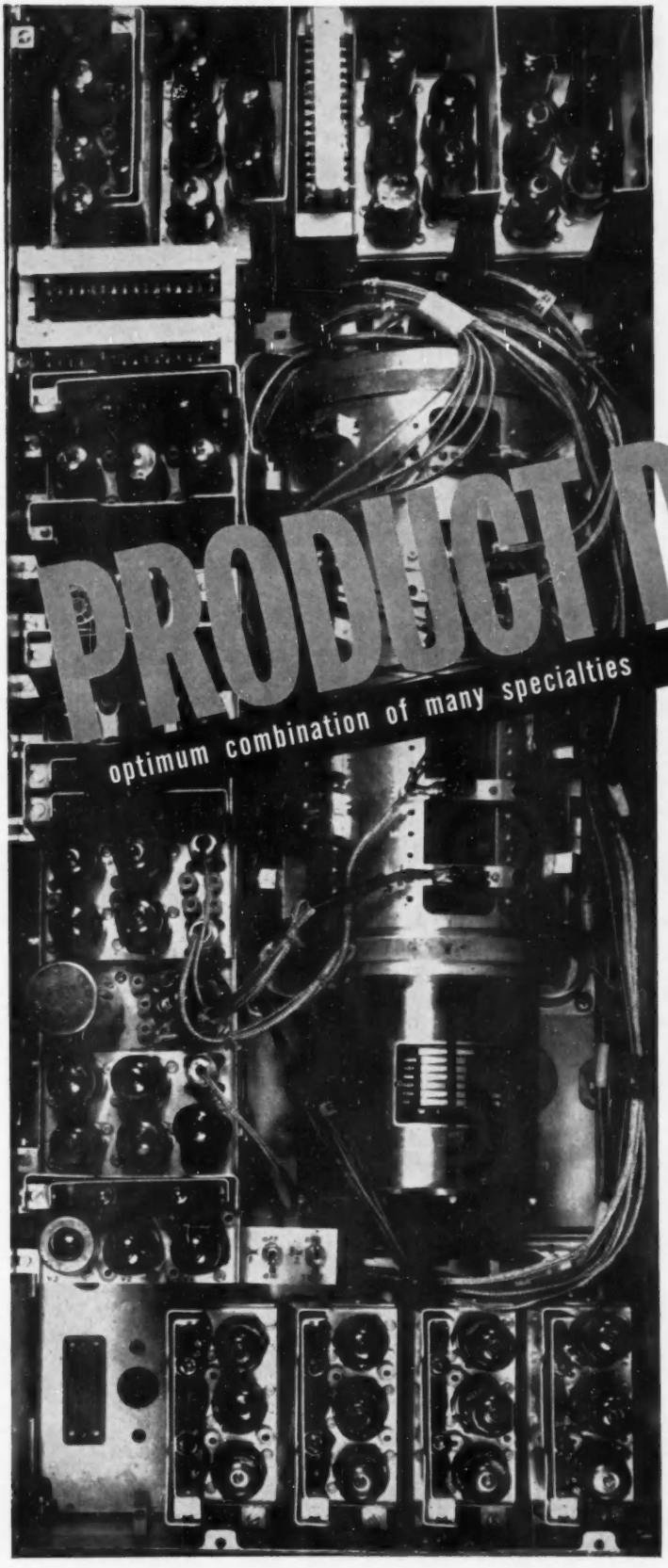
▶Another change at Convair-Astronautics (others: CtE, June, p. 210) spotlights **Charles S. Ames,** formerly chief design engineer for Convair's ICBM program, who has been named chief project engineer for the Atlas missile. Now on special assignment to Patrick AFB, Ames is being temporarily replaced at Astronautics by **Lloyd Munson,** a design engineer at Convair-Fort Worth.

▶**J. C. Larson,** a 15-year man with GE, has left to join Rotron Mfg. Co. of Woodstock, N. Y., as assistant chief engineer. He will be in charge of new product development. His work at GE embraced refrigeration engineering, air flow and heat transfer.

▶New arrivals at Bjorksten Research Laboratories, Inc., of Madison, Wis., are: **Robert T. Nagler,** formerly with Olin-Mathieson Chemical Corp. as a ballistics engineer and process engineering superintendent, named executive vice-president; **Stuart O. Fiedler,** a former research man with du Pont and Industrial Rayon, who returns to BRL as vice-president after nine years; and **Harvey R. Worthington,** a wartime staff member of MIT's Technology Radiation Laboratory, named acting vice-president in charge of the Physics Div.

OBITUARY

Claire D. (Chuck) Finnell, sales manager for analog computers, Berkeley Div. of Beckman Instruments, Inc. He was 33.



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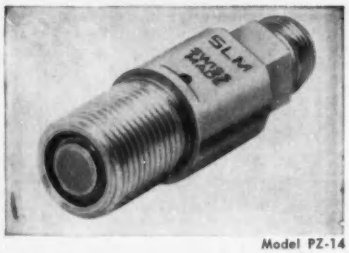
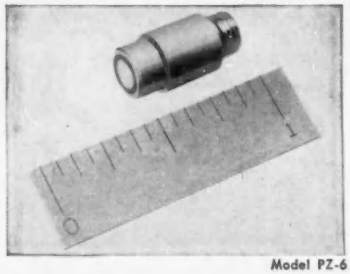


Model PZ-14



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The SLM Pressure Pickup, combined with special low-noise cables and a Kistler Piezo-Calibrator-Amplifier (required to couple pickups to oscilloscopes or recorders) constitutes the Kistler SLM Pressure Indicator. For complete information, request Bulletins PI-114, PZ-14 and PZ-6.

Kistler Instrument Corp., Dept. CE, 15 Webster St., North Tonawanda, N. Y.

ABSTRACTS

Data-Gatherer Speeds Boiler Tests

From "A Discussion of an Application of an Automatic Digital Data Collecting System to Boiler Testing" by J. H. Bail, West Penn Power Co.; C. E. Jones, The Babcock & Wilcox Co.; and H. T. Hoffman, Bailey Meter Co. Paper presented at the ASME Semi-Annual meeting, San Francisco, Calif., June 9-13, 1957.

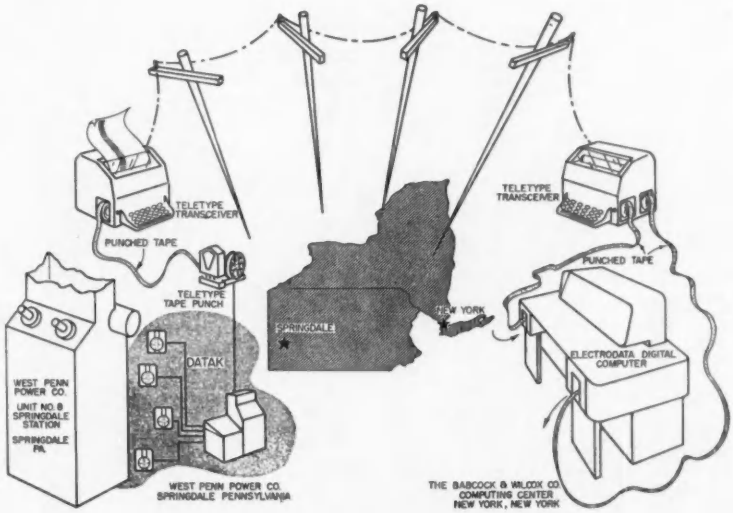
When the Bailey Meter Co. and The Babcock & Wilcox Co. joined forces to study applications of automatic data-taking, one specific objective was the reduction of manpower and time required for field testing boilers. They envisioned and ultimately developed a system (see sketch below) that would:

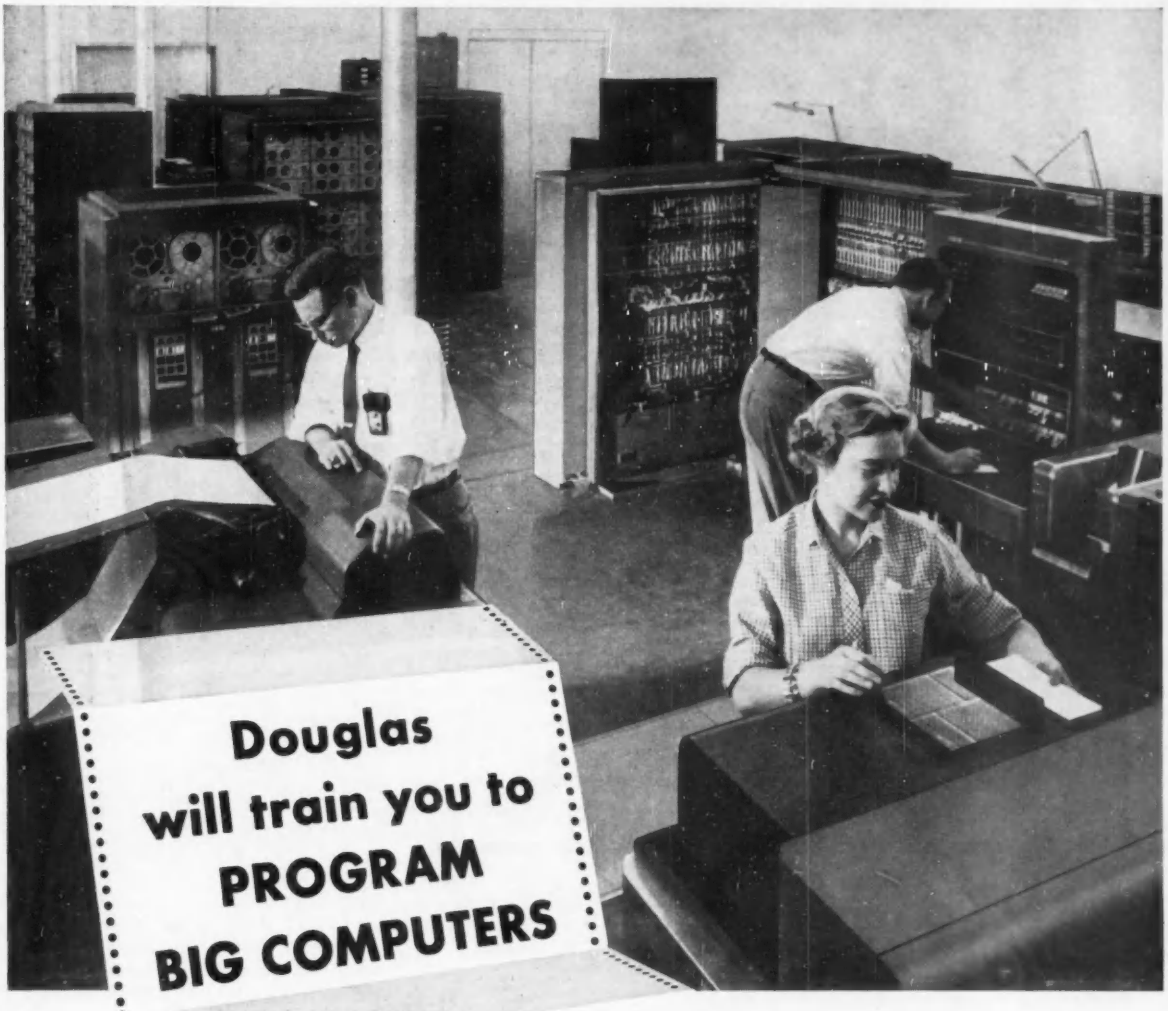
- scan sequentially a large number of process variables (temperatures, pressures, flows, and oxygen content) throughout a boiler and its auxiliary equipment
- convert each value to a standardized analog signal
- encode these analog signals in digital form
- punch out a paper tape for transmission to a remote computing center, and receive computed results back at the test site.

This system, called DATAK, was installed and debugged at the West Penn Power Co.'s Springdale Station. The boiler tested was a B&W reheat type rated at 950,000 lb per hr of steam at 1,550 psig, 1,000 deg F superheat out, and 1,000 deg F reheat. Between Aug. 22 and Sept. 17, 1956, 322 test runs were made without equipment failure. The instrumentation setup permitted the calculation of 1) boiler efficiency, 2) heat absorbed in each part of the convection pass, 3) gas temperature entering and leaving each section of the convection pass, and 4) overall conductance of each major section of the convection pass.

The quality of both the original data and the calculated results can be evaluated only by considering the sources of error that exist in the system. Errors are introduced at the primary elements, at the scanners, and in the analog-to-digital conversion process. Others, termed random errors, are either inherent in the equipment or induced by environment. Careful examination of these error sources led the investigators to the conclusion that system calibration remained stable enough throughout any one test to permit direct comparison of computed results without using correction factors. Because of a time limit on the Springdale tests, no attempt was made to achieve absolute calibration. Thus, the real value of these tests was to establish the reliability and repeatability of the DATAK equipment.

In general, the authors, representing maker and user, feel that the system can produce results at least equal to those obtained manually. The





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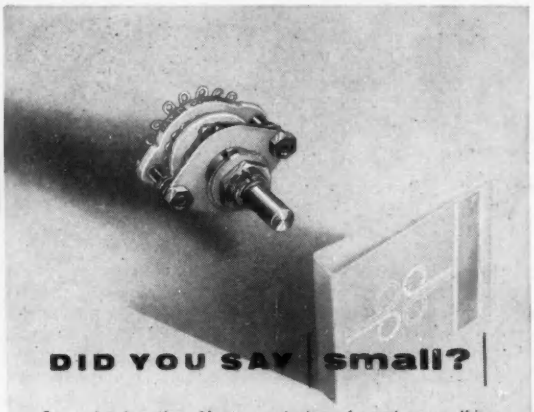

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These units can be "ganged" with up to 8 decks with slight mechanical modifications. 2 or 3 poles per deck may also be obtained as standard. Prototypes can be delivered within 2 weeks.

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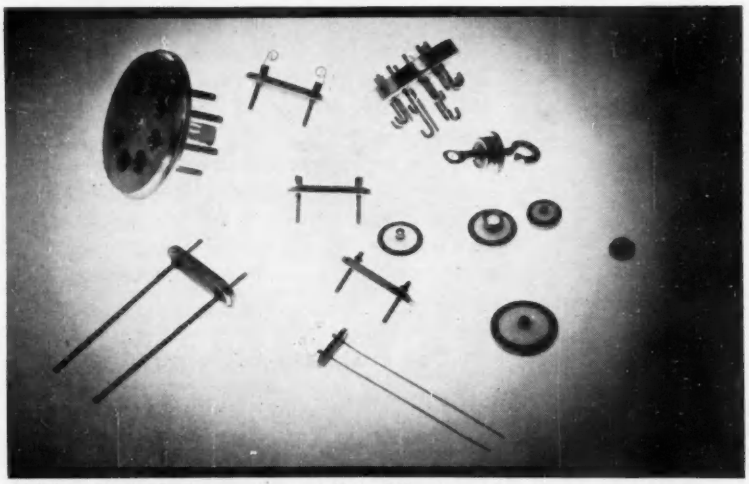

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reliability and quality of the test has been established, and the questions of absolute accuracy can easily be resolved. On the other hand, relative costs and the ability to take a new kind of look at the boiler are areas not so easily evaluated. DATAK can obtain all temperature, pressure, flow, and draft data on a boiler and turbine in about 3 min. This speed of data collecting opens the possibility of taking "snapshots" of the unit rather than time exposures; it affords an opportunity to study boiler operation in an entirely new manner.

Cyclic Decoder

From "A Cyclic Digital-to-Analog Decoder" by G. H. Myers, Rome Air Development Center, Griffis AFB, N. Y. Paper 49.2, presented at the Institute of Radio Engineers National Convention, New York, March 18-21, 1957.

Decoders that convert a binary number into a voltage which is proportional to that number may be classified as weighting decoders or counting decoders. A weighting decoder has many voltage or current sources weighted in a binary manner (such as 1 volt, 2 volts, 4 volts, etc.), and appropriate sources are turned on or off to provide the proper output—a dc voltage whose amplitude is proportional to the original number. When a counting decoder is used, a constant voltage is connected to an external load while a given amount is subtracted from the binary number at a fixed rate. The voltage is disconnected when the resulting number passes through zero, producing a pulse whose amplitude is constant but whose duration is proportional to the original binary number. If the duration-modulated pulse is the input to a properly-designed low-pass filter, the amplitude of the output pulse will then be proportional to the original number.

It has been long recognized that counting decoders require much simpler circuitry than weighting decoders. Their principal difficulty has been slow speed. If a computer is used in a control system with analog inputs and outputs, the maximum bandwidth of the system is one-half the reciprocal of the computing cycle (or sampling time). If a counting decoder is used which produces one output pulse every computing cycle, the bandwidth of the filter required to obtain the amplitude-modulated output is considerably less than this maximum. This diffi-

culty also exists, although to a lesser degree, with a weighting decoder. The maximum theoretical bandwidth may be approached by decoding the binary number many times during the computing cycle (thus producing during each computing cycle a short train of pulses with equal durations). However, since the original number is destroyed by the subtraction process, such schemes have usually used an extra register to store this number. The extra register, with its associated circuitry, causes the counting decoder to lose most of its economy.

Myers describes a counting decoder which permits a number to be decoded many times in a computing cycle without sacrificing the economy of the basic, simple counting decoder. If a binary number is placed in a register and a fixed amount is continually subtracted from it, the original number will reappear after a constant time interval. Thus, it is only necessary to start the duration-modulated pulse whenever the original number is present (a known instant) and to stop it when the number passes through zero.

Vanguard's Controls

From "Mechanical Aspects of the Vanguard Flight Control System" by F. Gordon Sholes, The Martin Co. Paper presented at the American Rocket Society Spring meeting, Washington, D. C. April 3-6, 1957.

Placing a 21.5-lb. 20-in. sphere in an orbit 300 miles above the earth's surface at a velocity of 18,000 mph requires a vehicle with a fairly sophisticated control system. The vehicle designed to achieve these unprecedented ends is the Vanguard, an 11-ton, 70-ft, three-stage rocket built by The Martin Co. of Baltimore. This rocket has no fins or external control surfaces of any kind; its pitch and yaw are controlled by the rocket engines themselves. Gimbal-mounted, the engines may be tilted to change direction of the thrust vector and thus steer the vehicle.

The first stage, which lifts the rocket to an altitude of 35 miles and gives it a final velocity of about 3,700 mph, is powered by a General Electric rocket engine and is propelled by liquid oxygen and kerosene. The thrust chamber, extending aft of the rocket structure, is gimballed by hydraulic actuators permitting 3.2 deg rotation of its longitudinal axis. This provides an attitude correcting moment equal to the engine thrust multiplied by the distance between the line of the thrust vector and the vehicle's center of gravity. Two double-acting actuators are used; they are placed at

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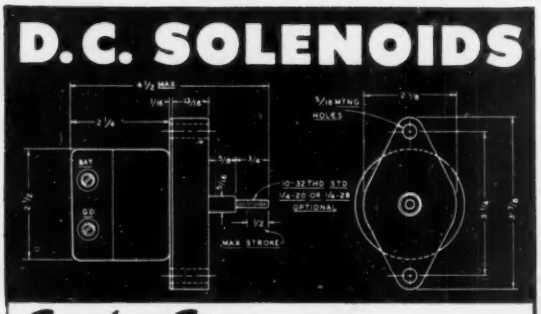


ABSTRACTS

90 deg to each other on the pitch and yaw axes, with their lines of action passing through the thrust chamber's center of percussion.

An hydraulic transfer valve and follow-up potentiometer mount directly on each actuator. Flow through the transfer valve is directly proportional to the input current from the control system. The follow-up potentiometer feeds back actuator position information to the autopilot. A small damping orifice in the actuator piston adds to the control system stability. Fluid power is provided by a constant volume pump driven by the hydrogen-peroxide turbine that drives the propellant pump. When not required by the actuator, pump flow is bypassed through a 1,500-psi relief valve.

Being coupled to the turbine, the constant-volume pump can deliver no pressure until the rocket is fired. To assure control at launch and to make final control system checks, an external source of hydraulic power is applied through automatic disconnect fittings.

Roll control is provided by special jets which use the exhaust steam of the hydrogen peroxide system. Nozzles are swiveled in a vertical plane clockwise or counterclockwise with a thrust of approximately 50 lb. These nozzles must be rotated in less than 0.1 sec. Solenoid-controlled pneumatic actuators perform this function, using helium as the working fluid.

After first-stage burnout and separation, the second stage, powered by an Aerojet-General liquid rocket engine, takes over. This stage provides a powered flight to an altitude of 130 miles, and a coasting flight after burnout to the 300-mile orbiting altitude. Velocity at this point is about 8,500 mph and is parallel to the earth's surface.

The second-stage engine is gimballed in the same manner as the first stage and uses a similar hydraulic system. However, since there is no propellant pump in the second stage, an electric motor pump provides the fluid power. Roll is controlled by exhausting propane gas through small jets.

Second-stage coasting flight is very critical because it is the guidance system's last chance to line up the rocket in the correct angular attitude for a successful orbit. The third stage has no guidance system; its course is established by the position of the second stage at separation. During this critical coasting phase, small jets, fed by residual gas in the helium tank,

control the vehicle's attitude in pitch and yaw as well as roll.

When the rocket reaches injection altitude, a coasting time computer gives the signal to spin the third stage. Rockets driving a spin table burn for about 1 sec and accelerate the third stage to about 150 rpm. Two retro rockets then retard the second stage while the spin stabilized third stage coasts clear and ignites. At 18,000 mph burnout and separation of the third stage occurs and the satellite is placed.

Refinery Simulation

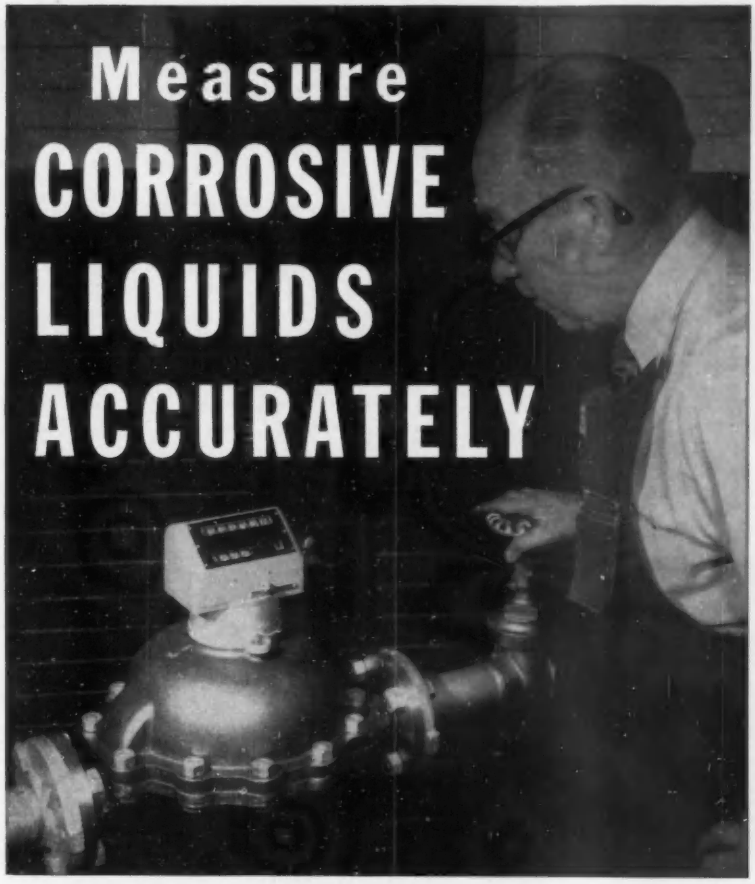
From "Use of Computers in Refinery Simulation" by A. F. Pixley, IBM Petroleum Dept. Paper presented at the ISA Instrumentation and Control Symposium, Berkeley, Calif., May 14, 1957.

In the modern petroleum refinery, scheduling of operations is always a difficult problem. Its objective is to produce finished products in desired quantity from given or potential crude oils. Of the many interdependent variables that exist, some can be controlled and some result from uncontrollable conditions. Management's task is to examine those that can be controlled and select conditions that are optimum according to some prescribed criterion, such as minimum cost or maximum profit.

The best approach at present is to simulate the refinery on a digital computer. The choice of a digital rather than an analog computer was made for several reasons. An analog computer is a rather specialized machine, while a digital computer, when not busy on the simulation problem, can handle other engineering calculations as well as accounting functions. Also, analog computers are inherently less accurate.

Given input data such as crude slate, product specifications, specialty requirements, operating conditions, and cost information, the computer determines: final opening parameters in the form of temperatures, pressures, charge rates, etc.; apportionment of intermediate streams; yields and quality of each output product; and profit analysis.

In this instance, the simulation function comprises six major sections: crude distillation, cracking, processing the light ends, fuel oil balancing, gasolene blending, and economics. In the author's opinion, the catalytic cracking studies represent the most valuable function. Analysis of the principle variables in a cracking unit has, in some cases, resulted in savings of $2-$3,000 per day.



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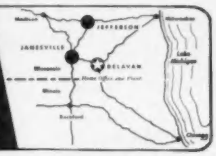

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NEW BOOKS

Applied Math

MATHEMATICS AND COMPUTERS by G. R. *Stibitz* and J. A. *Larrivee*. 228 pp. *Published by McGraw-Hill Book Co., Inc., New York*, 1957. $5.00.

The authors map the broad field of applied mathematics, emphasizing automatic computers as sober, unintelligent, but useful tools for science, technology, and business.

The book is for the layman who wants to know how mathematics and computers fit into scientific effort, and for engineers and scientists who are competent in their own specialties, but who have little knowledge of this particular field.

The authors handle their subject in an easy, but sometimes too-lighthearted, fashion. An example drawn from everyday experience usually follows each easily-read topic. Each section contains semi-humorous and allusive phrases that represent quite a departure from the ponderous style of other math books. This reviewer has not yet made up his own mind whether this aids or hinders, for though novel, the approach is sometimes disconcerting.

Electronics Updated

PROCEEDINGS OF THE NATIONAL ELECTRONICS CONFERENCE, Oct. 1-3, 1956, *Chicago, Ill.* Vol. 12, 1956. 1,095 pp. *Sold by National Electronics Conference, 84 E. Randolph St., Chicago 1, Ill.* $5.00.

The annual get-togethers sponsored by the National Electronics Conference offer first-rate information on electronics theory and application. The latest conference—1956—devoted sessions to instrumentation; servo application and theory; data storage and processing systems; magnetic amplifiers; solid-state devices, applications, and electronics; automation techniques; quality control and reliability; and medical electronics.

This volume, recently published by the NEC, covers the 118 papers presented in 24 sessions. Some indication of the breadth of coverage can be obtained from a survey of paper titles: application of solid-state amplifiers and control devices in modern autopilot circuits, a transistor-operated magnetic core memory, stability criterion for digital feedback control systems, coding a continuous information source, and nuclear reactor control.

Other papers of interest are: circuit design for reliability, a nuclear magnetic resonance moisture meter, a noncontacting tracing head for auto-

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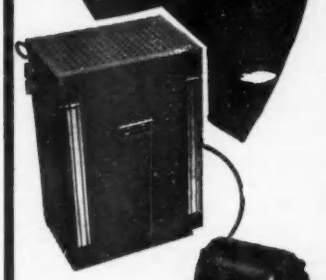

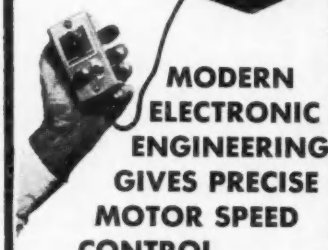

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matic contour following, and a relationship between rise time and peak power in servomechanisms.

Briefly Noted . . .

PROCEEDINGS OF THE NATIONAL SIMULATION CONFERENCE. *January 1956. 210 pp. Published by the Department of Electrical Engineering, Southern Methodist University, Dallas, Tex.* $5.00.

These proceedings contain the 35 papers presented at the first simulation conference sponsored by AIEE, IRE, ACM, and SMU. They are devoted, for the most part, to the design of simulation apparatus to be used in analog computer studies of an overall system. Units simulated include flight tables, microwave units, cathode ray tubes, and servos. Methods of electroanalogical simulation are also discussed.

T. J. Higgins
Madison, Wis.

TRANSISTOR CIRCUIT ENGINEERING *edited by R. F. Shea. 468 pp. Published by John Wiley & Sons, Inc., New York City, 1957.* $12.00.

Shea worked with 12 contributors on this companion to his 1953 book on "Principles of Transistor Circuits." The objective here is a proper mixture of transistor theory and circuit application. Thus, chapters on transistor audio, dc tuned, and video amplifiers, on oscillators, modulation, mixing, and detection, on transient response and pulse circuits, and on systems and special circuits follow introductory material on transistor characteristics, equivalent circuits, and bias and stabilization.

HANDBOOK OF SEMICONDUCTOR ELECTRONICS, *edited by L. P. Hunter. 20 sections with varying number of pages. Published by McGraw-Hill Book Co., Inc., New York, 1956.* $12.00.

This practical, comprehensive manual by 13 specialists covers the physics, technology, and circuit applications of transistors, diodes, and photocells. The organization facilitates ready access to information: the table of contents details subject coverage; the list of symbols, starting with general rules for interpreting subscripts, vectors, etc., contains the definition of each symbol used, and the page of its first appearance; and an exhaustive, 68-page bibliography in back contains references to publications on semiconductors, transistors, rectifiers, and related materials from 1936 on.

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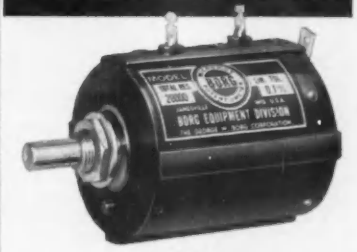

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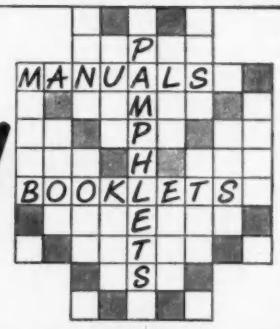

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WHAT'S AHEAD: MEETINGS

AUGUST

American Society of Mechanical Engineers, National Conference on Heat Transfer and Industrial Exhibit, Hetzel Union Building, Pennsylvania State University, University Park, Pa. Aug. 11-14

Radio-Electronics-Television Manufacturers Association (RETMA) Symposium on Numerical Control Systems for Machine Tools, Ambassador Hotel, Los Angeles Aug. 17-18

Institute of Radio Engineers, Professional Group on Automatic Control, Fairmount Hotel, San Francisco Aug. 19

Western Electronic Show and Convention (WESCON), Fairmount Hotel and Cow Palace, San Francisco Aug. 20-23

American Institute of Electrical Engineers, Pacific General Meeting, Pasco High School, Pasco, Wash. Aug. 26-30

Instrument Society of America, First International Symposium on Gas Chromatography, Michigan State University, Kellogg Center, East Lansing, Mich. Aug. 28-30

SEPTEMBER

Institute of Radio Engineers, PGIE, 2nd Special Technical Conference on Magnetic Amplifiers, Hotel Penn Sheraton, Pittsburgh Sept. 4-6

Instrument Society of America, 12th Annual International Conference and Exhibit, Cleveland Auditorium, Cleveland, Ohio Sept. 9-13

Institute of Radio Engineers, Symposium on Industrial Electronics (Transducers, Components, and Systems for Industrial Electronic Control), Morrison Hotel, Chicago Sept. 24-25

OCTOBER

National Electronics Conference, 13th Annual, Hotel Sherman, Chicago Oct. 7-9

American Institute of Electrical Engineers, Fall General Meeting, Hotel Morrison, Chicago Oct. 7-11

American Institute of Electrical Engineers, Feedback Control Systems Conference, Haddon Hall Hotel, Atlantic City, N. J. Oct. 16-18

Is Industry Creating A New Breed of "Bonus Babies"?

THE STARTING SALARIES offered to this year's June graduates give the impression that industry is creating a new breed of "bonus babies." This is the term baseball fans apply to sturdy youngsters whose talent for hitting and throwing gets them payments of up to $100,000 and other benefits for signing a contract.

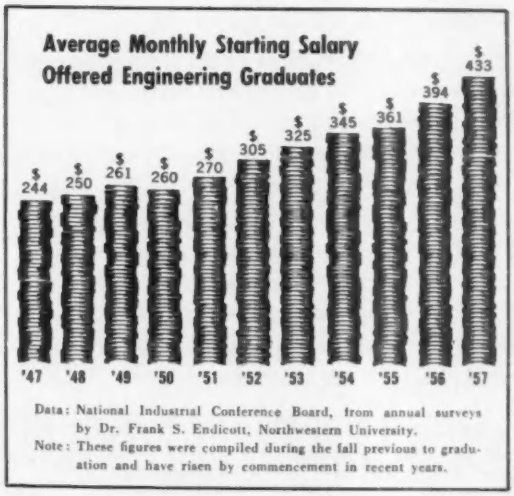
For several years industry's demand for young college graduates, especially in science and engineering, has outrun the number receiving degrees. Competition for these young people has steadily pushed up the starting salaries and has induced many companies to indulge in lavish recruiting programs. This year engineering graduates are being offered well over $400 a month, and even liberal arts graduates find numerous offers at $400 or more. Only ten years ago the salaries offered senior engineering students averaged less than $250 a month.

But any employer who assumes that high starting salaries alone will assure him the number of June graduates he wants is likely to be disappointed. A recent study by the McGraw-Hill Classified Advertising Division shows that most young engineers and scientists going into industry are more interested in their opportunities and in a company's future than they are in the size of their first paycheck.

Money Isn't Everything

In the McGraw-Hill survey, 2,596 recently-hired engineers and scientists employed in 57 companies listed the factors they had considered before accepting a position. The replies of the younger engineers and scientists—those with less than five years' experience — have great significance for employers who want to make any impression in the highly competitive market for college graduates.

- **Potential growth of the company** was listed by more young engineers and scientists than any of the 42 other items on the list as a factor that influenced greatly their decision in accepting a position.
- **Challenging opportunity** was second.
- **The company's prestige and reputation** ranked third.



Data: National Industrial Conference Board, from annual surveys by Dr. Frank S. Endicott, Northwestern University.
Note: These figures were compiled during the fall previous to graduation and have risen by commencement in recent years.

● **Progressive research and development program** was fourth.

● **Starting salary** ranked only **seventh.**

Job and Future Most Important

As a group, the factors relating to the nature of the job, its future and the company's future had by far the greatest influence in attracting young engineers and scientists to their present positions. These include three of the top four attractions—potential growth of the company, a challenging opportunity and a progressive research and development program. Other factors in this group are the company's facilities, quick advancement, self-direction or little supervision, chance to work in a certain field, small size of company and rewards for individual accomplishment.

The second most important group of attractions had to do with prestige. These include the company's prestige and reputation, executive or professional standing and association with leading men in the field. **Third in importance were financial considerations**—starting salary, regular salary increases, financing of relocation, paid vacations and holidays.

A less important group of factors influencing young scientists and engineers were essentially social. Geographic location and educational facilities in vicinity ranked fairly high. But recreational facilities, suburban or country living, pleasant housing and cultural considerations had little appeal.

Ranking lowest, by a good margin, were factors having to do with security—permanent position; health, life and surgical insurance; retirement or pension plan; and sick leave.

It is interesting to note that some of the factors which influenced the **smallest** percentage of young engineers and scientists were country club memberships, use of company car, at-cost or low-cost eating place, travel opportunities abroad and being able to buy the company's products at a discount.

A Lesson For Employers

The lesson of this survey to employers who hope to recruit more young engineers and scientists is clear. High salaries and other financial appeals are important. But, **at a time when high starting salaries are offered in abundance, our young graduates are interested even more in being with companies that will grow and in jobs that will permit them to grow. They are interested in jobs that offer opportunities for advancement, financially and professionally.**

* * *

Were the young scientists and engineers who participated in the survey trying to impress somebody with their motives? If so, it could only have been to impress themselves, for all were asked to return their questionnaires unsigned.

What Factors Influence the Job Selections of Young Engineers and Scientists?

Factors Influencing Decision Greatly	Percent Listing Factor
Potential growth of company	55%
Challenging opportunity	53
Company's prestige, reputation	44
Progressive research and development program	41
Geographic location	37
Permanent position	35
Starting salary	34
Educational facilities in vicinity	33
Regular salary increases	31
Chance to work on specific project, or in certain field	27
Company's facilities (laboratories, technical libraries, etc.)	25
Tuition for graduate study	25

Based on replies by recently-hired engineers and scientists with less than five years' experience to questionnaire distributed by McGraw-Hill Classified Advertising Division.

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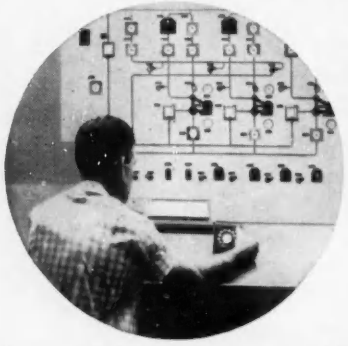

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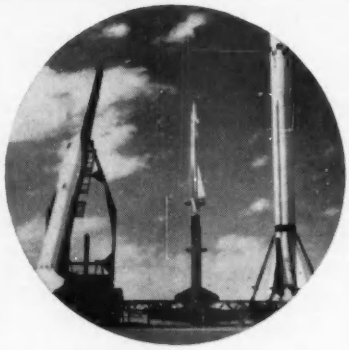

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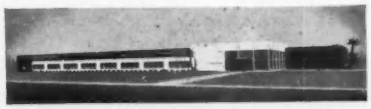

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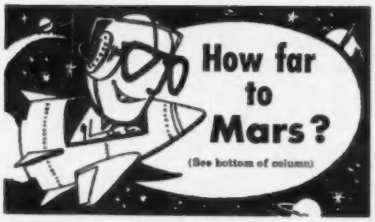

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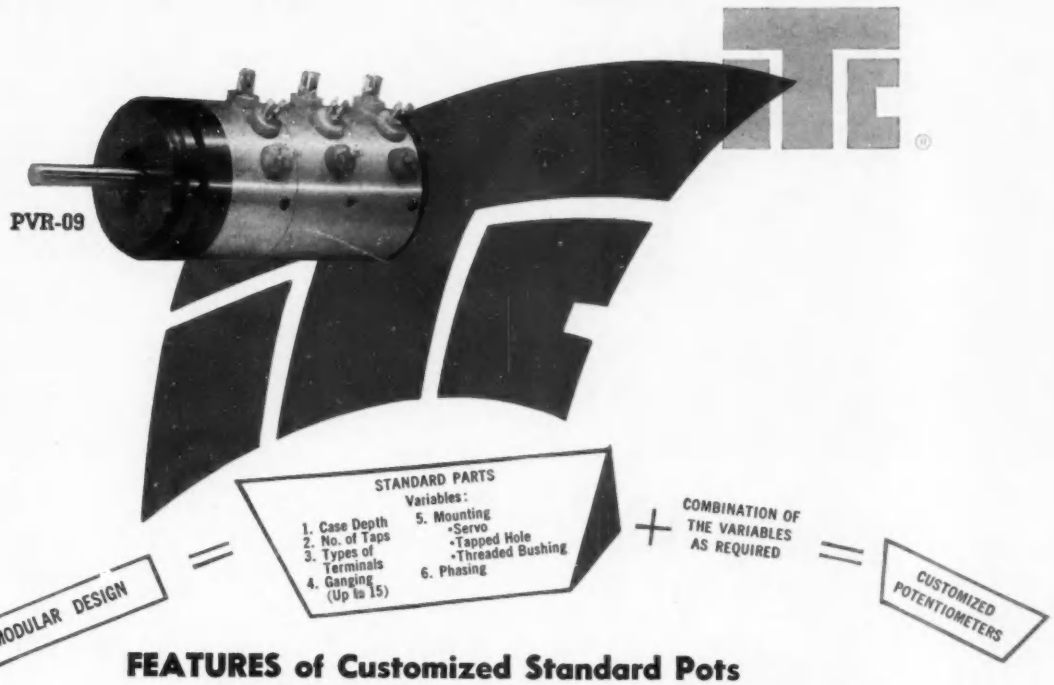

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THE KING and the TAILOR

There was once a king who was very fond of beautiful clothes. They said of him that he had a suit of clothes for every day in the year . . . for every kind of sport, royal affair, or holiday occasion.

One day, word reached the king that a tailor in a nearby town was able to create the most magnificent garments imaginable. The tailor's name was Ahem.

The king sent for Ahem and commissioned him to make some forty suits for the forthcoming harvest festival. All the suits were to be delivered in forty days. The king made it quite clear to Ahem that if the suits pleased him, Ahem would be rewarded handsomely . . . and if they didn't . . . well, Ahem would lose more than his union card!

This royal commission had Ahem just a little worried for he discovered before leaving the palace that the king's last tailor was dispatched rather abruptly. It seems the king felt the last suit the tailor had made was a bit *baggy* . . . here . . . here . . . and here.

The actual truth of the matter was that the king was baggy . . . here . . . here . . . and here!

And the more Ahem thought about it, the more he realized the king was much too fat to look well in anything. By the time Ahem arrived home, his spirits were so low he was scarcely able to greet his sweet wife. Whereupon she urged him to reveal that which troubled him so.

"Alas," he said, "this royal commission is my undoing." And he proceeded to tell his wife about his sad plight. When he was through, his wife threw back her head and laughed. "Don't worry," she said, "the solution is really quite simple . . . *tailor the king as well as the suits!*"

"But how might this be done," he said. With a twinkle in her eye, she replied, "make all the sporting clothes first and encourage the king to try them out in the heat of daily competition. Since the king has such a great interest in this undertaking, I'm sure he'll rise to the bait."

Ahem did as wife bade him and, Allah be praised, things worked out better than he had hoped. The king entered the whole affair with youthful enthusiasm . . . rising early in the morning to try his new riding cape, competing for long hours in his new fencing jacket, riding hither and yon in his new hunting outfit.

And so the days passed . . . inch by inch and tuck by tuck, Ahem tailored the king as he tailored the suits. Needless to say at the end of forty days the suits were delivered and the king was very pleased . . . and so was Ahem because he had such a clever wife.

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